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Diagnostic Analyzer for Gearboxes (DAG): User's Guide

Version 3.1 for Microsoft Windows 3.1

Vinay B. Jammu and Kourosh Danai

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Prepared for
Lewis Research Center
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Space Administration

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1997

DIAGNOSTIC ANALYZER FOR GEARBOXES (DAG):
Version 3.1 for Microsoft Windows 3.1

USER'S GUIDE

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1. INTRODUCTION

The Diagnostic Analyzer for Gearboxes (DAG) software has been developed by Process Automation Laboratory, University of Massachusetts at Amherst with funding from the U.S. Army Research Laboratory, and the NASA Lewis Research Center for performing intelligent fault diagnosis of gearboxes which do not have any seeded fault-vibration data. This software is designed to run on a PC with Microsoft Windows version 3.1. This chapter describes the procedures for installing and testing DAG as well as overview of the methodology used by DAG for gearbox diagnosis, a list of references for obtaining more information on the diagnostic methodology, and information for contacting the authors of the software.

1.1 COMPUTER REQUIREMENTS

- Recommended: A PC with a fast 486 processor (66MHz) with 16MB RAM.
- 4MB of hard disk space on the C: drive of the computer.
- Microsoft Windows 3.1 operating system.
- Windows 3.1 should be in the directory C:\WINDOWS. A sub-directory C:\WINDOWS\SYSTEM must exist. If these are not the setting for your computer, then after installing DAG according to instructions below, copy the file GRID.VBX from the C:\DAG directory to the WINDOWS\SYSTEM directory on your computer.

1.2 INSTRUCTIONS FOR INSTALLING OF DAG

1. Run the install program from the DAG software floppy. Example a:\install
2. The install program creates the directory C:\DAG on the hard disk of your computer, installs the DAG files, and copies the file GRID.VBX to C:\WINDOWS\SYSTEM directory. It also copies data files associated with an OH-58A gearbox to C:\DAG\EXAMPLES\OH58A directory.
3. If your MS-Windows is not installed in the directory C:\WINDOWS directory, then copy GRID.VBX to the WINDOWS\SYSTEM directory on your computer.

1.3 TESTING DAG

1. Start windows and run the program C:\DAG\GEARDIAG.EXE from windows by choosing the menu item File-Run.
2. This will start the DAG software. A DAG window will appear on the screen.
3. Choose the menu item File-Open in the DAG window.

4. A File Open dialog box appears. Select the directory C:\DAG\EXAMPLES\OH58A in this dialog box.
5. Select the file AOH58A.DAG, and click the Ok Button in the dialog box. The file associated with OH-58A gearbox will be opened and displayed in DAG.
6. Choose menu item Diagnosis-Full Diagnosis. This will run the Fault Detection Networks, Single Category-Based Classifier and Structure-Based Connectionist Network for fault detection, flagging, and fault isolation. This task may take up to 5 minutes depending on the computer speed.
7. After the tasks are completed, results are automatically displayed in preview mode. The screen changes to preview mode where results will be displayed in a rectangular box corresponding to the printer paper size.

1.4 OVERVIEW OF METHOD

DAG uses specialized unsupervised and knowledge based-neural networks for performing gearbox diagnosis. These neural networks were developed at the Process Automation Lab at the University of Massachusetts at Amherst in a doctoral research program. An overview of the fault detection and diagnosis method used by DAG is shown in Figure 1.

In order to perform gearbox diagnosis, the DAG software requires a graphical representation of the gearbox and a set of vibration features obtained by processing the vibration signal recorded from the gearbox using a signal analyzer. Given this information, the software uses an unsupervised neural network referred to as the Fault Detection Network (FDN) to identify the occurrence of faults, and a pattern classifier called Single Category-Based Classifier (SCBC) for abnormality-scaling of individual vibration features. The abnormality-scaled vibration features are then used as inputs to a Structure-Based Connectionist Network (SBCN) for identifying faults in gearbox subsystems and components. The weights of the SBCN represent its diagnostic knowledge and are derived from the structure of the gearbox graphically presented in DAG. The outputs of SBCN are fault possibility values between 0 and 1 for individual subsystems and components in the gearbox with a 1 representing a definite fault and a 0 representing normality.

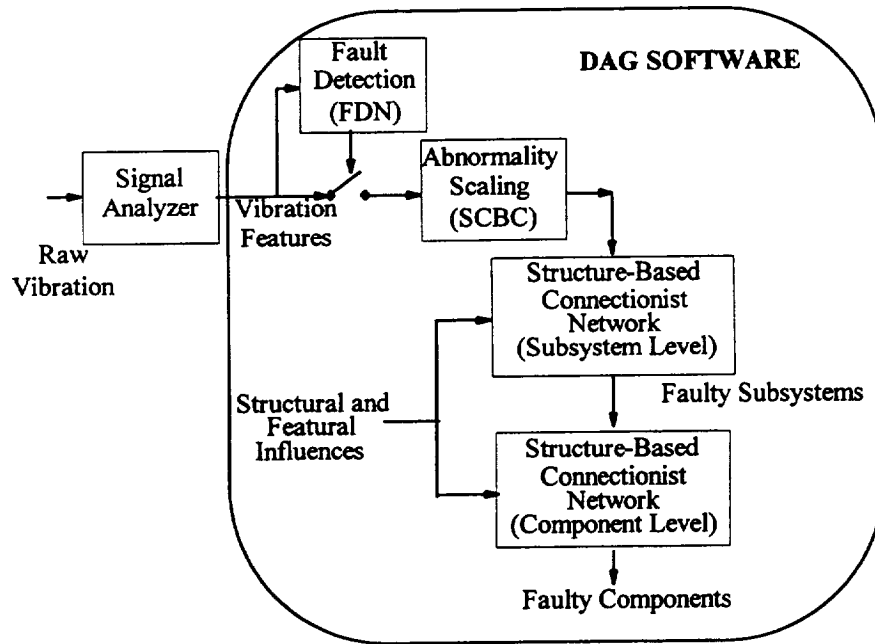


Figure 1. Overview of the fault detection and diagnosis method used in the DAG software.

The diagnostic knowledge used by the SBCN is of two forms: Structural and Featural knowledge. Structural knowledge is derived by the DAG software automatically using the graphical representation of gearbox. This knowledge represents the relation between an abnormal vibration signal in an accelerometer and a fault in a subsystem or a component. Structural knowledge is represented in form of *influences* which take fuzzy values between 0 and 1, with a 0 representing no effect of fault on the accelerometer and 1 representing a definite effect of fault on the accelerometer. Featural knowledge is also represented in form of fuzzy influences and is used to represent a relation between individual vibration features and gearbox faults. The user of the software is required to enter the featural influences into DAG software using its table format interface.

To obtain more detailed information about the neural networks and diagnostic methodology used in DAG please refer to list of reference given in the next section or contact the authors of the software.

1.5 REFERENCES

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1.6 CONTACT INFORMATION

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<http://www.ecs.umass.edu/mie/labs/danai/>

2. FIVE STEPS TO GEARBOX DIAGNOSIS

This chapter explains the five basic steps for performing fault diagnosis of a new gearbox in DAG.

STEP 1: Construct Gearbox Structure

Creating a Gear

Creating a Bearing

Creating a Shaft

Creating a Sensor

Connecting the Components

STEP 2: Define Vibration Paths

STEP 3: Define Subsystems

STEP 4: Add Featural Influence

Adding Features and Their Influences

Defining Groups

STEP 5: Full Diagnosis

Viewing Results: View Mode

Printing Results

2.1 STEP 1: CONSTRUCT GEARBOX STRUCTURE

To perform fault diagnosis for a gearbox, DAG requires information on the number of gears, bearings, shafts, and sensors and their structural connections. This step explains the procedure to create gears, bearings, shafts, and sensors and their structural connections.

Creating a Gear

Creating a Bearing

Creating a Shaft

Creating a Sensor

Connecting the Components

2.1.1 CREATING A GEAR

To represent a gearbox component such as a gear, this component has to first be created in DAG. To create a gear, select menu item Create-Gear. A gear dialog box for setting various properties (e.g., gear name, gear teeth, gear diameter) of the gear appears on the screen. The Gear Number is an internal number used by DAG to identify the component. Do not modify it. The two compulsory items that must be entered in the dialog are Gearbox Name and Gear Name. Others

items in the dialog box are optional (see Chapter 3). Click on the Ok Button at the bottom of the dialog box to create the component. Clicking on Cancel Button aborts the creation of gear.

If the Ok Button is clicked, an icon with a picture of gear on will appear at the top left hand corner of the window, with the name of the gear appearing in short form at the bottom of the icon (e.g., Spiral Bevel Pinion's short form appears as SBP). This gear icon in DAG represents the physical gear in the gearbox.

2.1.2 CREATING A BEARING

To create a bearing, select menu item Create-Bearing. A bearing dialog box for setting the properties of the bearing will appear. The compulsory items that need to be entered in this dialog box are Gearbox Name (if empty) and Bearing Name (Note: If the correct Gearbox Name automatically appears in the bearing dialog box, it need not be modified.) Click on Ok button to create the bearing or Cancel to abort.

2.1.3 CREATING A SHAFT

Similarly, to create a shaft, select menu item Create-Shaft. A shaft dialog box appears for which the Gearbox name and Shaft Name must be compulsorily entered. Click on Ok button to create the shaft or Cancel to abort.

2.1.4 CREATING A SENSOR

To create a sensor (accelerometer), select menu item Create-Sensor. A Sensor dialog box appears on the screen. All the items in this dialog box must be filled for fault diagnosis to work properly.

See Sensor dialog box for examples of items in the sensor dialog box.

Click on Ok button to create the sensor or Cancel to abort.

See Also: Sensor dialog box
 Sensor Data File Format

2.1.5 CONNECTING THE COMPONENT ICONS

Once all the gearbox components are created, they should be connected in DAG to represent the structural connections physically present among the components in the gearbox. For example, two gears that are meshing physically in the gearbox are to be connected in DAG to represent the mesh. These physical connections are represented in DAG by a line drawn between the two component icons.

To connect two components icons in DAG, select menu item Link-Connect. Then click the left mouse button when the mouse-pointer is on top of the first component icon to be connected. When you move the mouse, you will see a line appear from this component to the mouse pointer.

Move the mouse-pointer onto the second component icon that you want to connect to, and click the left mouse button again. This will draw a line between the two component icons to represent the physical connection between the two components in gearbox.

2.2 STEP 2: DEFINE VIBRATION PATHS

In this step the user will define for DAG, the major vibration flow paths in the gearbox. This step will require the user to have some knowledge of the most important paths in the gearbox which contribute to the vibration transfer from the components to the sensor. An example of vibration flow path would be the path from a meshing gear through its supporting shaft and bearing to the sensor. This path would define for DAG the vibration flow occurring from the gear to the sensor through the supporting shaft and bearing. This path will then be used by DAG's diagnostic knowledge extraction routines to assign structural influences to relate component faults to sensor readings. Constructing a comprehensive set of vibration paths is important since the quality of diagnosis (by the Structure-Based Connectionist Network) critically depends on the comprehensiveness of the vibration paths.

To construct a vibration flow path, select menu item Link-Define Vibration Path. First click the left mouse button on top of the sensor icon. (Note: As the vibration path defines vibration flow from components to a sensor, the first icon that is clicked on must be a sensor.) A thick line will appear on the DAG window from the clicked sensor to the current mouse-pointer position. Click the left mouse button on the next component in the vibration flow path. A thick line will be drawn between the sensor and the component to represent vibration flow from this component to the sensor. Continue clicking on other components in the flow path. Note that a physical connection in form of connection line must exist between two components for vibration flow to be defined between them. (See 'CONNECTING THE COMPONENT ICONS' for more information.) To end the vibration flow path, double click the left mouse button on top of the last components in the path. All the thick lines will be erased from the screen, but DAG creates an internal data structure to represent the vibration flow path.

2.3 STEP 3: DEFINE SUBSYSTEMS

Diagnosis in DAG is performed by two different sub-sections of the Structure-Based Connectionist Network (SBCN). While in the first sub-section, faulty subsystems are isolated, in the second sub-section faulty component are isolated. In order to perform fault subsystem isolation, DAG requires the user to group the gearbox components into subsystems. Components can be grouped into subsystems using the Structural Influence Matrix Dialog Box.

To define subsystems, select menu item Influences-Generate Structural Influences if structural influences have not been generated. A Structural Influence Matrix Dialog Box appears on the screen. In this dialog box, a structural influence table is displayed at the top with buttons at the bottom of the dialog box. The rows in the structural influence table represent the gearbox sensors while the columns represent the gearbox components. Both row and columns are titled with the names of the sensors and component respectively. In the second row of this table information on the subsystems each of the component belongs to is listed. Initially only the characters 'SS'

appear in each of the columns in this row. This is because the components are not assigned to any subsystem yet.

To form a group of components to define a subsystem, click the left mouse button the Define Subsystem Button at the bottom of the dialog box. Then click the left mouse button on all the component names in the influence table (or the corresponding columns) that belong to this subsystems. The 'SS' characters in the second row associated with the clicked components will change to 'SS 1' to indicate that all these components belong to Subsystem No. 1. (Caution should be employed in defining subsystems, as the only method to undo subsystems categorization is to click the left mouse button on the Cancel Button.)

To end defining a subsystem, click on the End Subsystem Button at the bottom of the dialog box.

After grouping all the component into subsystems, click on the Ok Button to save the changes, or Cancel Button to abort changes.

2.4 STEP 4: ADD FEATURAL INFLUENCES

In DAG, while the structural influences are constructed automatically by DAG's diagnostic knowledge extraction routines using the vibration flow paths, the featural influences have be manually entered into DAG. The featural influences which represent the relation between individual vibration features and component faults can be constructed using the menu item Influences-Add Featural Influences. Note that featural influences must be generated only after all the components in the gearbox are created (see STEP 1: CONSTRUCTING THE GEARBOX STRUCTURE).

2.4.1 ADDING FEATURES AND THEIR INFLUENCES

Select menu item Influences-Add Featural Influences. A dialog box with a table will appear on the screen. In this table, the total number of rows corresponds to the maximum number of features listed in all the sensors in gearbox (see CREATING A SENSOR). If the number of features listed for a sensor is not the same, use only the features common to all sensors for diagnosis. The number of columns in the table corresponds to the number of components in gearbox.

To enter a feature, click the left mouse button in the second row, third column cell with the text 'INSERT' in it. This text will be copied into the text box at the bottom left corner above the Help button in the dialog box. Enter the name of the feature into the text box and click on the Update Value Button on its right. The feature name will be copied from the text box into the second row third column cell in the table. Avoid using long names for features (recommended length of about 10 characters).

It should be noted that DAG will associate vibration features in the third column in the table in the order they appear to the columns in the sensor data file. Therefore, the sequence of features entered in this table MUST correspond to the sequence of features in the sensor data files (see SENSOR DATA FILE FORMAT). For example, consider the four columns of data from the

SENSOR DATA FILE FORMAT section. If the first, second, third and fourth columns correspond to Skewness, Kurtosis, Crest Factor, and Peak to Peak features as:

<i>Skewness</i>	<i>Kurtosis</i>	<i>Crest Factor</i>	<i>Peak to Peak</i>
1.00	1.00	1.00	1.00
1.21	1.46	1.00	1.04
1.42	2.09	1.03	1.90
1.39	4.99	2.11	1.99
1.03	4.34	3.21	3.22
1.39	4.99	2.11	1.99
1.42	2.09	1.03	1.90

then, the first four features in third column of the table must be Skewness, Kurtosis, Crest Factor, and Peak to Peak in that order.

After entering the feature name, its relation to the component faults must be entered by the user in the row corresponding to the feature. The relation between features and component faults is represented by the five fuzzy variable, NIL, LOW, MEDIUM, HIGH, and DEFINITE. These are abbreviated -, L, M, H, and D respectively in the table. While a NIL represents no relation between feature and component fault, a DEFINITE indicates that the feature will be definitely affected by the component fault. General guidelines used to assign the featural influences are:

<i>Relation Between</i>	<i>Assign Influence</i>
Gear Features and Gears	HIGH
Bearing Features and Bearings	HIGH
General Features and Gears and Bearings	MEDIUM

Gear features in the above table include features such as Cepstrum and signal averaged features (processed at the gear meshing frequencies). Bearing features include Cepstrum (processed at the bearing rotational frequencies), Envelope Analysis Features (Envelope Base Energy, Envelope Tone Energy, etc.). General Features include Statistical Features such as Root Mean Square value, Skewness, Kurtosis, etc.

To enter a fuzzy variable to relate a feature to a component, click the left mouse button in the cell corresponding to the feature and component in the table. Then enter -, N, L, M, H or D in the text box at the bottom left corner of the dialog box and click the Update Value Button. The fuzzy variable in the text box will be copied to the corresponding cell in the table. Similarly enter the rest of the fuzzy influences between feature and all the components in the gearbox.

2.4.2 DEFINING GROUPS

In order to perform abnormality-scaling of features, the Single Category-Based Classifier (SCBC) requires grouping information for the features. The grouping information indicates the features that belong in a group, such that when a component fault occurs the SCBC tries to

achieve homogeneity in classification. For example, a group of features could be all those features related to a specific gear such as a sun gear. SCBC tries to maintain homogeneity in features in this group such that it tries to categorize all the features as normal or abnormal.

In order to form groups of features, click the left mouse button on the Define Group Button. Then click the left mouse button in all the rows associated with this group. To end the group click the left mouse button on the End Group Button. Features in the columns that were clicked will be categorized into one group. Click on Define Group Button again to define the next group.

To end entering featural influences click on the Ok Button. To end without saving the information entered, click on Cancel Button.

2.5 STEP 5: FULL DIAGNOSIS

In order to perform fault diagnosis the following information built in the previous 3 steps is required:

Sensor Test and Normal Data Files	User must enter these in the Sensor Dialog Box
Structural Influences	DAG generates these based on user defined vibration Flow Paths.
Featural Influences	User must enter using Menu item Influences-Add Featural Influences.

Once these three pieces of information are constructed, Fault Detection, Abnormality Scaling and Fault Diagnosis can be simultaneously performed by selecting the menu item Diagnosis-Full Diagnosis. The operation of full diagnosis might take up to 10 minutes depending on the number of features and complexity of gearbox. When full diagnosis is selected, the following operations take place in DAG:

Fault Detection by Fault Detection Network (FDN):

- The memory required to read the features in DAG is assigned.
- The data files are read.
- Fault detection Thresholds are computed using the normal data files.
- Fault Detection Networks are created, one for each sensor.
- Fault detection is performed.
- Adaptation of FDN's weights is performed at each step of fault detection.
- The results are displayed in text mode.

Abnormality-Scaling by Single Category-Based Classifier (SCBC)

- The memory required to read the features in DAG is assigned (if necessary).
- The data files are read (if necessary).
- SCBC Thresholds are computed using the normal data files.
- SCBC's are created, one for each sensor.
- Abnormality-Scaling is performed.
- Adaptation of SCBC's weights is performed at each step of Scaling.

(No results are displayed for Abnormality-Scaling.)

Fault Diagnosis by Structure-Based Connectionist Network (SBCN)

The memory required to read the features in DAG is assigned (if necessary).

The data files are read (if necessary).

Fault detection is performed (if necessary).

Abnormality Scaling by SCBC is performed (if necessary).

Subsystem and Component Level SBCN's are created.

Structural Influences are prepared.

Featural Influences are prepared.

Fault diagnosis is performed.

Results are displayed in text format.

2.5.1 VIEWING RESULTS: VIEW MODE

After the Fault Detection Networks (FDNs) perform fault detection, the results are displayed in text mode. The results appear in view mode (view mode displays results as they would be appear on paper when printed). Note that results will appear in full page mode initially and may be too small to see. Click the left mouse button on the button Zoom In at the top of screen. The results will be re-displayed on the screen in an enlarged format. Click on the same button to zoom in more into the results, while click on the Zoom Out Button to zoom out to full page mode.

The results from FDN would be titled:

FAULT DETECTION NETWORKS: FAULT IDENTIFICATION RESULTS

Below this title, information regarding the number of sensors, components, number of feature vectors, etc., will appear. After this, a table of fault detection results appears. The rows in this table represent the feature vectors for each sample reading (days, patterns, or snapshots) and the columns represent the sensors. The first row of this table lists the abbreviated names of sensors (e.g., Sensor 1 abbreviated as S1). The next row lists the thresholds for each of these sensors computed using the normal data. The third row lists the maximum value of output (pre-thresholded) from each of the FDNs for each sensor (these are the maximum pre-thresholded values in the corresponding column). From the fourth row onwards, the fault detection results are included, with a 0 indicating that the features from the sensor are normal, while a 1 indicating a abnormal readings from that sensor. Each subsequent row lists the fault detection results for subsequent feature vector samples.

The diagnostic results from the Structure-Based Connectionist Network (SBCN) would be titled:

STRUCTURE-BASED CONNECTIONIST NETWORK: FAULT SUBSYSTEM ISOLATION RESULTS.

The table under this title shows the fault possibility values associated with faulty subsystems obtained from the first sub-section of SBCN. The first column in this table is titled 'Pat' representing the pattern number. The total number of patterns in this table corresponds to the number of feature vectors entered in the Sensor Dialog Box (see CREATING A SENSOR). Column two onwards represent the fault possibility values for each subsystem. The results in each column are titled 'SS 1', 'SS 2', etc. representing subsystems 1, 2, etc. The fault possibility

values are numbers between 0 and 1 with a 0 representing normal component and a 1 representing a definite fault in the component.

The fault component isolation results from the second sub-section of SBCN are titled:

STRUCTURE-BASED CONNECTIONIST NETWORK: FAULT COMPONENT ISOLATION RESULTS.

The table under this title shows the fault possibility values for faulty components. The first column in this table is titled 'Pat', and as before represents the pattern number. The total number of patterns in this table corresponds to the number of patterns entered in the Sensor Dialog Box (see CREATING A SENSOR). Column two onwards represent the fault possibility values for each component. The results in each column are titled with name of the component in short form of each component (e.g., Spiral Bevel Pinion's short form is SBP). The fault possibility values are numbers between 0 and 1 with a 0 representing normal component and a 1 representing a definite fault in the component. Note that if the number of components in the gearbox is large, and all the component results do not fit in one table, a separate table titled:

Faulty Component Isolation Results. Continued...

would appear to present results for the rest of components.

A second mode of viewing results is the View Mode. This mode which is similar to the fault detection view mode display, can be activated by selecting the menu item File-View Results. The DAG window with component icons would be erased and a view mode window appears. In this mode, results are displayed in a square box representing the paper (they would appear exactly the same if they were printed using a printer). Note that results will appear in full page mode initially and may be too small to see. Click the left mouse button on the button Zoom In at the top of screen. The results will be re-displayed on the screen in an enlarged format. Click on the same button to zoom in more into the results, while click on the Zoom Out Button to zoom out to full page mode.

2.5.2 PRINTING RESULTS

Both fault detection results from Fault Detection Networks (FDNs) and fault identification results from Structure-Based Connectionist Network (SBCN) can be printed using a printer installed in Windows 3.1. To print results, select menu item File-Print Results. A Print Dialog Box appears, wherein the user can select the pages to printed, and the number of copies to produce. Clicking the left mouse button on the Setup Button in the Print Dialog Box, a Printer Setup dialog box appears. In this dialog box the user can select the printer to be used, the orientation (portrait or landscape), paper size and source tray. A further Options Button in this dialog box allow the user to control the print intensity (light or dark) and dithering (coarse, fine, etc.).

After selecting the pages and copies in the Print Dialog Box, click the left mouse button on Ok to print the results. Click on Cancel Button to abort.

3. KNOWING THE DAG USER INTERFACE

This chapter explains the interface items that appear in the DAG window such as menus and tool bars which can be used to give commands to DAG. The interface items explained in this chapter are:

Menu

Button Bar Dialog Box

Toolbar

Accelerator Keys

Status Bar

3.1 MENU COMMANDS

Menu refers to the text items that are displayed across the top of the DAG window, below the title of the window. These text items can be used to issue the following commands to DAG:

File menu

Edit menu

Create menu

Link menu

Influences menu

Diagnosis menu

Options menu

Help menu

Quit menu

3.1.1 FILE MENU COMMANDS

The File menu offers the following commands:

<u>New</u>	Closes any currently open gearbox file and creates a new gearbox file.
<u>Open</u>	Opens an existing gearbox file from hard disk or floppy.
<u>Close</u>	Closes an opened gearbox file WITHOUT prompting the using for saving the file.
<u>Save</u>	Saves an opened gearbox file using the same file name WITHOUT prompting the user.
<u>Save As</u>	Saves an opened gearbox file to a specified file name.
<u>Change Test Sets</u>	Allows the user to change the test data files for each sensor so that fault diagnosis can be performed for different test data.
<u>Print Gearbox</u>	Prints the gearbox structure and the compulsory information on the components

<u>View Gearbox</u>	Displays the gearbox structure and the compulsory information on components as they would appear on paper when printed.
<u>Print Results</u>	Prints the fault detection and diagnosis results.
<u>View Results</u>	Displays the fault detection and diagnosis results as they would appear on paper when printed.
<u>Print Influences</u>	Prints the structural and featural influences.
<u>View Influences</u>	Displays the structural and featural influences as they would appear on paper when printed.
<u>Printer Setup</u>	Selects printer and printer connection.
<u>Exit</u>	Exits DAG.

3.1.1.1 New command (File menu)

Use this command to create a new gearbox file in DAG. Closes any currently open gearbox file WITHOUT prompting the user.

Shortcuts

Buttonbar:



Accelerator Key: F12

See Also: [Open command](#)
[Close command](#)

3.1.1.2 Open command (File menu)

Use this command to open a gearbox file already existing on the hard disk or floppy. On clicking the left mouse button on this menu item, a [File Open dialog box](#) appears. This is a standard windows dialog box used to open files already existing. The dialog box can be used to select a drive, directory, and file to be opened. For examples see [File Open dialog box](#). Note that by convention, all the DAG files have the extension '.DAG' (e.g., OH58A.DAG, S61.DAG, etc.).

To open the file, select the correct drive, directory, and file, and click the left mouse button on the Ok Button. This will causes DAG to check the file for a DAG file format. If the file format is correct, then DAG reads the file for the gearbox information and displays the gearbox in the DAG window.

Shortcuts

Toolbar:



Keys: F10

See Also: [File Open dialog box](#)
[New command](#)
[Close command](#)

3.1.1.3 File Open dialog box

The following options allow you to specify which file to open:

File Name

Type or select the filename you want to open. Example: OH58A.DAG.

List Files of Type

Although, All Files (*.*) appears in the text box for this item, only files with '.DAG' extension should be opened.

Drives

Select the drive in which the DAG file that you want to open is located. Example: A:, B:, C:.

Directories

Select the directory in which the DAG file that you want to open. Example: C:\GEARBOX

3.1.1.4 Close command (File menu)

Use this command to close an opened gearbox file. Unsaved gearbox files will be lost. Since in the current version of DAG only one gearbox file can be opened at a time, choosing the close command will also exit the DAG application. You can also close a gearbox file and exit DAG by double clicking the left mouse button on the Control menu button as shown below:



See Also:

New command
Open command
Exit command

3.1.1.5 Save command (File menu)

Use this command to save the gearbox file to its current name and directory. When you save a document for the first time, DAG displays the Save As dialog box so you can name your document. If you want to change the name and directory of an existing document before you save it, choose the Save As command.

Shortcuts

Toolbar:



Keys:

F2

See Also:

Save As dialog box
Save As command

3.1.1.6 Save As command (File menu)

Use this command to save the current gearbox file into a different drive, directory, and file assigned by you in the Save As dialog box

See Also: Save As dialog box
 Save command

3.1.1.7 File Save As dialog box

The following options allow you to specify the name and location of the file you're about to save:

File Name

Type or select the filename you want to the gearbox file to be saved into. Example: OH58ANEW.DAG.

List Files of Type

Although, All Files (*.*) appears in the text box for this item, only files with '.DAG' extension should be used for saving.

Drives

Select the drive in which the DAG file is to be saved. Example: A:, B:, C:.

Directories

Select the directory in which the DAG file is to be saved. Example: C:\GEARBOX

3.1.1.8 Change Test Sets command (File menu)

Use this command to change the test data files for each sensor so that fault diagnosis can be performed for a different test data. A Change Test Sets dialog box, appears where the user can enter a new directory path, test data file, normal data file, and number of feature vectors in both these files for each of the sensors in the gearbox. The user can get information on the various sensors by clicking the left mouse button on the Previous and Next Buttons in the Change Test Sets dialog box.

Note that the user has to usually change test data file names for all the sensors to point to the new test data files. If the number of sensors in a gearbox is large, this becomes a cumbersome task. In order to make this task less cumbersome, DAG has a feature wherein the changes made in test data file for the FIRST sensor that appears when the Change Test Sets dialog box appears on screen is automatically copied to the rest of the sensor. For example, if information for Sensor No. 3 appears first when this command is selected, then changing test1_3.dat to test2_3.dat would automatically change the test data file information for all the other sensors (e.g., originally test1_5.dat for Test No. 1, Sensor No. 5 would change to test2_5.dat to represent Test No. 2, Sensor No. 5).

Similarly changes made to other items such as directory path, number of patterns, etc. for the FIRST sensor only would be automatically copied to other sensors.

Shortcuts

Toolbar:



Keys:

F3

See Also: [Change Test Sets dialog box](#)

3.1.1.9 Change Test Sets dialog box

The following options allow you to specify the test set information for each of the gearbox sensors:

Sensor Number

This is an internal number used by DAG to identify the sensor. Do not modify it.

Default Path for Files

This is directory and drive where DAG will look for Test Data File and Normal Data File.

Example: C:\GEARBOX\OH58A

Sensor Name

This is name of sensor which to you can use to identify it. Example: Sensor 1.

Test Data File

Data file containing the vibration features from this sensor. There is a special format for naming test data files. The file name must contain as its last three characters, the test number, and underscore, and the sensor number. A file extension of '.dat' is advised. Example: test1_3.dat for data from Test No. 1, Sensor No. 3 or s604_5.dat for data from S60 gearbox for Test No. 4, Sensor No. 5. The vibration features in this file have to be in a special format. Refer to the DAG User's Guide's Chapter on 'Constructing the Gearbox Structure'.

Number of Feature Vectors

The total number of feature vectors in the Test Data File. Example: 9 for Test No. 1 for OH-58A gearbox. This number must be the same for all the sensors in the gearbox for a single set of test data files. Example: test1_1.dat, test1_2.dat, and test1_3.dat, which are Test Data Files for Sensor Nos. 1, 2, and 3 for Test No. 1 must be equal.

Normal Data File

Data file containing the normal vibration features for this sensor. There is a special format for naming the normal data files. The file name must contain as its last two characters, an underscore and the sensor number. A file extension of '.dat' is advised. Example: normal_3.dat for normal data from Sensor No. 3. The vibration features in this file have to be in a special format. Refer to the DAG User's Guide's Chapter on 'Constructing the Gearbox Structure'.

Number of Normal Feature Vectors

The total number of normal feature vectors in the Normal Data File. Example: 26 for OH-58A gearbox. This number must be the same for all the sensors in the gearbox.

3.1.1.10 Print Gearbox command (File menu)

Use this command to print the gearbox structure and compulsory information on the components.

This command presents a Print dialog box, where you can specify the range of pages to be printed, the number of copies, and other printer setup options. The setup button in this dialog box brings up the Print Setup dialog box which allows the user to select the destination printer, portrait/landscape modes, and paper size.

Shortcuts

Keys: SHIFT+G

See Also: Print dialog box
Print Setup dialog box
View Gearbox

3.1.1.11 View Gearbox command (File menu)

Use this command to display the gearbox structure and the compulsory information on the gearbox components as they would appear on paper when printed.

When you choose this command, the main window will be replaced with a print preview window in which one or two pages will be displayed in their printed format. The View Toolbar offers you options to view either one or two pages at a time, move back and forth through the document, zoom in and out of pages, and initiate a print job.

See Also: View Toolbar
Print dialog box
Print Gearbox

3.1.1.12 Print Results command (File menu)

Use this command to print the fault detection and isolation results.

This command presents a Print dialog box, where you can specify the range of pages to be printed, the number of copies, and other printer setup options. The setup button in this dialog box brings up the Print Setup dialog box which allows the user to select the destination printer, portrait/landscape modes, and paper size.

Shortcuts

Toolbar:



Keys: SHIFT+R


See Also: Print dialog box
Print Setup dialog box
View Results

3.1.1.13 View Results command (File menu)

Use this command to display the results from fault detection and isolation as they would appear on paper when printed.

When you choose this command, the main window will be replaced with a print preview window in which one or two pages will be displayed in their printed format. The View Toolbar offers you options to view either one or two pages at a time, move back and forth through the document, zoom in and out of pages, and initiate a print job.

Shortcuts

Toolbar: 
Keys: SHIFT+V

See Also: View Toolbar
Print dialog box
Print Results

3.1.1.14 Print Influences command (File menu)

Use this command to print the structural and featural influences for the gearbox.

This command presents a Print dialog box, where you can specify the range of pages to be printed, the number of copies, and other printer setup options. The setup button in this dialog box brings up the Print Setup dialog box which allows the user to select the destination printer, portrait/landscape modes and paper size.

Shortcuts

Keys: SHIFT+I

See Also: Print dialog box
Print Setup dialog box
View Influences

3.1.1.15 View Influences command (File menu)

Use this command to display the structural and featural influences as they would appear on paper when printed.

When you choose this command, the main window will be replaced with a print preview window in which one or two pages will be displayed in their printed format. The View Toolbar offers you options to view either one or two pages at a time, move back and forth through the document, zoom in and out of pages, and initiate a print job.

See Also: View Toolbar
 Print dialog box
 Print Influences

3.1.1.16 Print dialog box

The following options allow you to specify how the gearbox structure or fault detection and diagnosis results or influence tables should be printed:

Printer

This is the active printer and printer connection. Choose the Setup option to change the printer and printer connection.

Setup

Displays a Print Setup dialog box, so you can select a printer and printer connection.

Print Range

Specify the pages you want to print:

- | | |
|------------------|---|
| All | Prints all the pages. |
| Selection | Prints the currently selected page. |
| Pages | Prints the range of pages you specify in the From and To boxes. |

Copies

Specify the number of copies you want to print for the above page range.

Collate Copies

Prints copies in page number order, instead of separated multiple copies of each page.

Print Quality

Select the quality of the printing. Generally, lower quality printing takes less time to produce.

3.1.1.17 View toolbar

The View toolbar appears when the gearbox structure, diagnostic results, or influence table are displayed on screen before printing by selecting File - View Gearbox, View Results, or View Influences. It offers the following options:

Print

Bring up the Print dialog box to start a print job.

Next Page

Preview the next page.

Prev Page

View the previous page.

One Page / Two Page

Preview one or two pages at a time.

Zoom In

Take a closer look at the page.

Zoom Out

Take a larger look at the page.

Close

Return from View mode to the DAG window.

3.1.1.18 Print Setup command (File menu)

Use this command to select a printer and a printer connection. This command presents a Print Setup dialog box, where you specify the printer and its connection. The following options allow you to select the destination printer and its connection.

Printer

Select the printer you want to use. Choose the Default Printer, or choose the Specific Printer option and select one of the current installed printers shown in the box. You install printers and configure ports using the Windows Control Panel.

Orientation

Choose Portrait or Landscape.

Paper Size

Select the size of paper that the document is to be printed on.

Paper Source

Some printers offer multiple trays for different paper sources. Specify the tray here.

Options

Displays a dialog box where you can make additional choices about printing, specific to the type of printer you have selected.

Network...

Choose this button to connect to a network location, assigning it a new drive letter.

3.1.1.19 1, 2, 3, 4 command (File menu)

Use the numbers and filenames listed at the bottom of the File menu to open the last four documents you closed. Choose the number that corresponds with the document you want to open.

3.1.1.20 Exit command (File menu)

Use this command to end DAG application. You can also use the Close command in the File menu to end DAG. Gearbox files that are not saved will be lost.

Shortcuts

Mouse: Double-click the application's Control menu button.



Keys: ALT+F4

3.1.2 EDIT MENU COMMANDS

The Edit menu offers the following commands:

<u>C</u> ut	Deletes the currently selected component icon and moves it to the clipboard. Not implemented in the current version of DAG.
<u>C</u> opy	Copies the currently selected component icon to the clipboard. Not implemented in the current version of DAG.
<u>P</u> aste	Pastes clipboard contents into the DAG window. Not implemented in the current version of DAG.
<u>D</u> elete	Deletes the currently selected component icon.
<u>M</u> ove	Moves the currently selected component icon. Not implemented in the current version of DAG.

3.1.2.1 Cut command (Edit menu)

Use this command to delete the currently selected component icon from the DAG window and place it in the clipboard. This is not implemented in the current version of DAG.

3.1.2.2 Copy command (Edit menu)

Use this command to copy the currently selected component icon onto the clipboard. This is not implemented in the current version of DAG.

3.1.2.3 Paste command (Edit menu)

Use this command to insert a copy of the clipboard contents into DAG window. This is not implemented in the current version of DAG.

3.1.2.4 Delete command (Edit menu)

Use this command to delete the currently selected component icon. A selected component icon has four small solid rectangles at its four corners. Once the component is deleted, it cannot be retrieved.

Shortcuts

Toolbar:



Keys:

DELETE

3.1.2.5 Move command (Edit menu)

Use this command to move the currently selected icon from its original position to a new position.

A selected component icon has four small solid rectangles at its four corners. This is not implemented in the current version of DAG.

3.1.3 CREATE MENU COMMANDS

The Create menu offers the following commands:

<u>G</u> ear	Creates a gear component icon.
<u>B</u> earing	Creates a bearing component icon.
<u>S</u> haft	Creates a shaft component icon.
<u>S</u> ensor	Creates a sensor component icon.
<u>O</u> ther	Creates a user defined component icon. Not implemented in the current version of DAG.

3.1.3.1 Create Gear command (Create menu)

Use this command to create a gear icon to represent an actual gear in the gearbox. A Gear dialog box will appear where the user can specify the gearbox name and gear name.

Shortcuts

Toolbar:



See Also: Gear dialog box
Create Bearing
Create Shaft
Create Sensor

3.1.3.2 Gear dialog box

The following options allow you to specify the information for each gear in the gearbox:

Gear Number

The Gear Number is an internal number used by DAG to identify the component. Do not modify it.

Machine Name

Enter the name of the gearbox. Example: OH58A.DAG, S60.DAG. The gearbox name entered when the first component (gear, bearing, shaft or sensor) is created will be copied to all the subsequent components.

Gear Name

Enter the name of gear that is being created. Example: Spiral Bevel Pinion, Ring Gear. The first character of each word in the component name will be used to form a short form name for the component, which appears below the component icon in the DAG window. Example: SBP, RG.

OPTIONAL:

Since the current version of DAG uses a simplified model of vibration attenuation, the following items in the dialog box are not used and hence, optional.

Gear Diameter

Enter the diameter of the gear in Meters.

Number of Teeth

Enter the number of teeth on the gear.

Helix Angle

Enter the helix angle in degree for the gear.

Modulus of Elasticity

Enter the modulus of elasticity for the material in Newton/Square meter.

Gear RPM

Enter the rotational speed of the gear in RPM.

Density of Material

Enter the density of the material in Kilograms/Cubic meter.

3.1.3.3 Create Bearing command (Create menu)

Use this command to create a bearing icon to represent an actual bearing in the gearbox. A Bearing dialog box will appear where the user can specify the gearbox name and bearing name.

Shortcuts

Toolbar:



See Also:

[Bearing dialog box](#)

[Create Gear](#)

[Create Shaft](#)

[Create Sensor](#)

3.1.3.4 Bearing dialog box

The following options allow you to specify the information for each bearing in the gearbox:

Bearing Number

This is an internal number used by DAG to identify the component. Do not modify it.

Machine Name

Enter the name of the gearbox. Example: OH58A.DAG, S60.DAG. The gearbox name entered when the first component (gear, bearing, shaft or sensor) is created will be copied to all the subsequent components.

Bearing Name

Enter the name of bearing that is being created. Example: Triplex Bearing, Planet Bearing. The first character of each word in the component name will be used to form a short form name for the component, which appears below the component icon in the DAG window. Example: TB, PB.

OPTIONAL:

Since the current version of DAG uses a simplified model of vibration attenuation, the following items in the dialog box are not used and hence, optional.

Bearing Type

Identify if the bearing is roller or ball type.

Number of Ball/Roller

Enter the number of balls/rollers in the bearing.

Ball/Roller Diameter

Enter the ball/roller diameter in Meters.

Roller Length

If the Bearing Type selected was roller, enter the length of the roller in Meters.

Contact Angle

Enter the contact angle for the bearing in Degrees.

Radial Load

Enter the radial load on the bearing in Newton.

Bearing RPM

Enter the rotational speed of the bearing in RPM.

Bearing Material

Enter the type of bearing material. Example: Steel.

3.1.3.5 Create Shaft command (Create menu)

Use this command to create a shaft icon to represent an actual shaft in the gearbox. A Shaft dialog box will appear where the user can specify the gearbox name and shaft name.

Shortcuts

Toolbar:



See Also: Shaft dialog box
Create Gear
Create Bearing
Create Sensor

3.1.3.6 Shaft dialog box

The following options allow you to specify the information for each shaft in the gearbox:

Shaft Number

This is an internal number used by DAG to identify the component. Do not modify it.

Machine Name

Enter the name of the gearbox. Example: OH58A.DAG, S60.DAG. The gearbox name entered when the first component (gear, bearing, shaft or sensor) is created will be copied to all the subsequent components.

Shaft Name

Enter the name of shaft that is being created. Example: Main Shaft. The first character of each word in the component name will be used to form a short form name for the component, which appears below the component icon in the DAG window. Example: MS

OPTIONAL:

Since the current version of DAG uses a simplified model of vibration attenuation, the following items in the dialog box are not used and hence, optional.

Shaft Type

Identify if the shaft is hollow or solid.

Shaft Length

Enter the length of the shaft in Meters.

Shaft Inner Diameter

Enter the inner diameter of the shaft in Meters, if the shaft is hollow.

Shaft Outer Diameter

Enter the inner diameter of the shaft in Meters.

Modulus of Elasticity

Enter the modulus of elasticity for the material in Newton/Square meter.

Density of Material

Enter the density of the material in Kilograms/Cubic meter.

3.1.3.7 Create Sensor command (Create menu)

Use this command to create a sensor icon to represent an actual sensor in the gearbox. A Sensor dialog box will appear where the user can specify the gearbox name, sensor name., test and normal data file names, number of features and feature vectors.

Shortcuts

Toolbar:



See Also: Sensor dialog box
 Create Gear
 Create Bearing
 Create Shaft

3.1.3.8 Sensor dialog box

The following options allow you to specify the information for each sensor in the gearbox. For more information on data file formats see Sensor Data File Formats. All items in this dialog box must be entered.

Sensor Number

This is an internal number used by DAG to identify the component. Do not modify it.

Machine Name

Enter the name of the gearbox. Example: OH58A.DAG, S60.DAG. The gearbox name entered when the first component (gear, bearing, shaft or sensor) is created will be copied to all the subsequent components.

Sensor Name

Enter the name of sensor that is being created. Example: Sensor 1, Accelerometer 3. The first character of each word in the component name will be used to form a short form name for the component, which appears below the component icon in the DAG window. Example: S1, A3.

Default Path for Files

This is directory and drive where DAG will look for Test Data Files and Normal Data Files. Example: C:\GEARBOX\OH58A

Number of Features

Enter the number of features that were extracted from the vibration data from this gearbox. Example: For the OH58A gearbox, the number of features extracted was 54. THE NUMBER OF FEATURES MUST BE THE SAME FOR ALL GEARBOX SENSORS IN BOTH TEST DATA FILES AS WELL AS NORMAL DATA FILES. See files starting with 'test' with extension '.dat' in the OH58A directory.

Test Data File Name

Enter the data file name containing the vibration features from this sensor. There is a special format for naming test data files. The file name must contain as its last three characters, the test number, and underscore, and the sensor number. A file extension of '.dat' is advised. Example: test1_3.dat for data from Test No. 1, Sensor No. 3 or s604_5.dat for data from S60 gearbox for Test No. 4, Sensor No. 5. The vibration features in this file have to be in a special format. Refer to the DAG User's Guide's Chapter on 'Constructing the Gearbox Structure'.

Number of Feature Vectors

Enter the total number of feature vectors in the Test Data File. Example: 9 for Test No. 1 for OH-58A gearbox. This number must be the same for all the sensors in the gearbox for a single set of test data files. Example: test1_1.dat, test1_2.dat, and test1_3.dat, which are Test Data Files for Sensor Nos. 1, 2, and 3 for Test No. 1 must be equal. See File test1_1.dat in the OH58A directory.

Normal Data File Name

Enter the data file name containing the normal vibration features for this sensor. There is a special format for naming the normal data files. The file name must contain as its last two characters, an underscore and the sensor number. A file extension of '.dat' is advised. Example: normal_3.dat for normal data from Sensor No. 3. The vibration features in this file have to be in a special format. Refer to the DAG User's Guide's Chapter on 'Constructing the Gearbox Structure'.

Number of Normal Feature Vectors

Enter the total number of normal feature vectors in the Normal Data File. Example: 26 for OH-58A gearbox. See File normal_1.dat in the OH58A directory. This number must be the same for all the sensors in the gearbox.

3.1.3.9 Sensor Data File Formats

In order for the sensor data files (both test data file and normal data file) to be read correctly by DAG, the data files must be in ASCII text format with the vibration features arranged in columns as:

1.00	1.00	1.00	1.00
1.21	1.46	1.00	1.04
1.42	2.09	1.03	1.90
1.39	4.99	2.11	1.99
1.03	4.34	3.21	3.22
1.39	4.99	2.11	1.99
1.42	2.09	1.03	1.90

In the above data file, the columns represent the features and the rows represent the feature vectors for each sample reading (sample vectors, days, patterns, or snapshots). In the example above, the number of features extracted from vibration from this sensor is 4 and the number of samples of feature vectors is 7.

Note that the data must be normalized before it is used as inputs to DAG. The normalization should be carried out such that the features for the first sample vector, which is assumed to be from a normal gearbox, are all 1's. The rest of the data in each column should be scaled in reference to the feature values from this particular sample. As an example, consider the first column of the above data file whose original non-normalized values are given as:

10.0
12.1
14.2
13.9
10.3
13.9
14.2

These feature values can be normalized by dividing rows 1 through 7 of the above column with the first feature value (10.0).

3.1.3.10 Create Other command (Create menu)

Use this command to create a user define icon to represent an special gearbox component. This is not Implemented in the current version of DAG.

3.1.4 LINK MENU COMMANDS

The Link menu offers the following commands:

<u>Connect</u>	Draws a line between two component icons to represent a physical link between them.
<u>Disconnect</u>	Removes a line between two component icons.
<u>Define Vibration Path</u>	Defines a primary vibration flow path in the gearbox.
<u>Show All Vibration Paths</u>	Displays all the vibration paths in the gearbox. Can also be used to delete vibration paths.
<u>Delete Vibration Path</u>	Deletes an existing vibration flow path.

3.1.4.1 Connect command (Link menu)

Use this command to connect two components by drawing a line between them to represent a physical link between them (e.g., gear mesh represented by two gear icons connected by a line). To connect two icons, select this menu item and click the left mouse button on the first icon, and then on the second. A single straight line with no break points is drawn to connect the two icons. To draw lines with multiple break point select this menu item, then first click the left mouse button on the first component icon. Define a break point by clicking on any point in the DAG window to draw a line from this point to the first component icon. Continue defining break point for the connection lines. To end the connection line, click on the second component which is to be connected to the first.

Shortcuts

Toolbar:



See Also: Disconnect

3.1.4.2 Disconnect command (Link menu)

Use this command to disconnect two components by removing the line between them. Removes a connection between two components. Select this menu item, click on the first component and then on the second. If a connection exists, it will be deleted by erasing the line between the two components. There is no need to click on intermediate break points for the line.

Shortcuts

Toolbar:



See Also: Connect

3.1.4.3 Define Vibration Path command (Link menu)

Use this command to define a primary vibration flow path to represent a major vibration flow path in the gearbox between the components and sensor. To define vibration path, select this menu item, and click the left mouse button on the sensor which is recording the vibration from this path. Then click on the components icons in path such that the component closest to the

sensor in DAG is physically close to the sensor in the gearbox. Keep clicking on all the components in the path in the sequence represented physically in the gearbox. No intermediate break points are allowed. To end the path, double click the left mouse button on the last component icon.

Shortcuts

Toolbar: 

See Also: [Show All Vibration Paths](#)
[Delete Vibration Path](#)

3.1.4.4 Show All Vibration Paths command(Link menu)

Use this command to displays all the vibration paths defined for the gearbox. A dialog box appears at bottom of DAG window which can be used to view the next/previous vibration paths or delete them.

See Also: [Define Vibration Path](#)
[Delete Vibration Path](#)

3.1.4.5 Delete Vibration Path command(Link menu)

Use this command to delete an existing vibration path. To delete a path, select this menu item, click first on the sensor in the path and the last component in the path. If a vibration path exists for this sensor-component pair, it will be deleted.

See Also: [Show All Vibration Paths](#)
[Delete Vibration Path](#)

3.1.5 INFLUENCES MENU COMMANDS

The Influences menu offers the following commands:

<u>Generate Structural Influences</u>	DAG generates new structural influences from the user defined vibration flow paths.
<u>Add Featural Influences</u>	Allows the user to enter featural influences into DAG.
<u>Modify Structural Influences</u>	Changes the previously generated structural influences.
<u>Modify Featural Influences</u>	Changes the previously added featural influences.

3.1.5.1 *Generate Structural Influences command(Influences menu)*

Use this command to generate new structural influences. The user defined vibration flow paths are used by DAG to generate structural influences. DAG displays the newly generated structural influences in a Structural Influence Dialog Box.

Note that any previous modifications to the structural influences will be lost as new influences will be generated when this menu item is selected. A simplified vibration attenuation model is used to assign influence between the sensor and the components in the vibration flow path. This item can also be used to assign gearbox components to various subsystems.

See Also: Add Featural Influences
 Modify Structural Influences
 Modify Featural Influences

3.1.5.2 *Add Featural Influences command(Influences menu)*

Use this command to enter the featural influences in DAG. DAG displays an empty Featural Influence Dialog Box. The component names appear in the first column of the table. The features and their associated influences on the components must be entered by the user.

This menu item can also be used to categorize features in groups which indicate gear or bearing related faults, and to define standard featural influences to be reused for other gearboxes.


See Also: Generate Structural Influences
 Modify Structural Influences
 Modify Featural Influences

3.1.5.3 *Modify Structural Influences command(Influences menu)*

Use this command to modify the previously generated structural influences. DAG displays the existing structural influences in a Structural Influence Dialog Box so that user could modify them.

This item can also be used to assign gearbox components to various subsystems.

Shortcuts

Toolbar: 

See Also: Generate Structural Influences
 Add Featural Influences
 Modify Featural Influences

3.1.5.4 Modify Featural Influences command(*Influences menu*)

Use this command to modify previously added featural influences. DAG displays the Featural Influence Dialog Box with previously added featural influences so that the user to could modify them. This item can also be used for grouping features and defining standard featural influences to be reused for other gearboxes.

Shortcuts

Toolbar:



See Also: Generate Structural Influences
Add Featural Influences
Modify Structural Influences

3.1.6 DIAGNOSIS MENU COMMANDS

The Diagnosis menu offers the following commands:

<u>Full Diagnosis</u>	Perform fault detection, flagging (abnormality-scaling), and fault isolation together.
<u>Fault Detection Only</u>	Performs fault detection only.
<u>Flagging Only</u>	Performs flagging (abnormality-scaling) only.
<u>Fault Isolation Only</u>	Performs fault isolation only.
<u>Supervised Training of SBCN</u>	Perform supervised training of SBCN after feature-fault data is available from the gearbox.
<u>Show Color Coded Results</u>	Displays the previously generated fault isolation results in color coded format.
<u>Make Fault Detection independent</u>	Do not multiply outputs of fault detection network (0 or 1) with outputs of SBCN.
<u>Make SBCN Levels Independent</u>	Do not multiply outputs of Level 1 SBCN with Level 2 SBCN.

3.1.6.1 Full Diagnosis command (*Diagnosis menu*)

Use this command to performs fault detection using the Fault Detection Networks (FDNs), flagging using Single Category-Based Classifier (SCBC), and Fault Isolation using the Structure-Based Connectionist Network (SBCN).

The estimated time for these computations is between 2-10 minutes. After completion of the three operations, fault detection and isolation results are be displayed in the view mode.

Shortcuts

Toolbar:



See Also: [Fault Detection Only](#)
 [Flagging Only](#)
 [Fault Isolation Only](#)
 [Show Color Coded Results](#)

3.1.6.2 Fault Detection Only command (Diagnosis menu)

Use this command to perform fault detection using the Fault Detection Networks (FDNs). After completion of this operation, fault detection results are displayed automatically in the view mode.

Shortcuts

Toolbar: 

See Also: [Full Diagnosis](#)
 [Flagging Only](#)
 [Fault Isolation Only](#)
 [Show Color Coded Results](#)

3.1.6.3 Flagging Only command (Diagnosis menu)


Use this command to perform flagging (abnormality-scaling) using the Single Category-Based Classifier (SCBC). Results are written to a file.

See Also: [Full Diagnosis](#)
 [Fault Detection Only](#)
 [Fault Isolation Only](#)
 [Show Color Coded Results](#)

3.1.6.4 Fault Isolation Only command (Diagnosis menu)

Use this command to perform fault isolation using the Structure-Based Connectionist Network (SBCN). After completion of fault isolation, component fault possibility values are automatically displayed in the color coded format.

Shortcuts

Toolbar: 

See Also: [Full Diagnosis](#)
 [Fault Detection Only](#)
 [Flagging Only](#)
 [Show Color Coded Results](#)

3.1.6.5 Supervised Training of SBCN command (Diagnosis menu)

Use this command to perform supervised training of the Structure-Based Connectionist Network (SBCN). This training can be performed only when feature-fault data for the gearbox is available. The training is performed by adapting the fuzzy influences of SBCN so as to reduce the error between the output of SBCN and the targets supplied by the user from physical inspection of the disassembled gearbox. The algorithm used in SBCN is a modified version of Least Mean Square Algorithm for single layered neural network.

It is recommended that training be performed only when the SBCN misdiagnoses gearbox faults and enough number of sample features associated with a fault are available. Clicking on this menu item shows a Train SBCN: Training Information dialog box. This dialog box can be used to set all the training information such as learning rate, data files to be used for training, number of iterations, etc.

See Also: Train SBCN: Training Information dialog box

3.1.6.6 Train SBCN: Training Information dialog box

The following options allow you to specify information for performing supervised training of the SBCN:

Sensor Number

This is an internal number used by DAG to identify the sensor. Do not modify it.

Default Path for Files

This is directory and drive where DAG will look for all the Training Data Files. Example:
C:\GEARBOX\OH58A

Sensor Name

Displays the sensor name for which the information is displayed in the dialog box. Do not modify it here. It can be modified, if necessary, in the Sensor dialog box.

Training Data File

Data file containing the vibration features from this sensor to be used for training. There is a special format for naming test data files. The file name must contain as its last two characters, a underscore, and the sensor number. A file extension of '.dat' is advised.

Example: train_3.dat for data from Training Set No. 3.

Number of Feature Vectors

The total number of feature vectors in the Training Data File. Example: 9 for Test No. 1 for OH-58A gearbox. This number must be the same for all the sensors in the gearbox for a single set of test data files. Example: train_1.dat, train_2.dat, and train_3.dat, which are Training Data Files for Sensor Nos. 1, 2, and 3 must be equal. See File train_1.n54 in the OH58A directory.

Subsystem Targets File Name

Data file containing 0 and 1 to represent a normal or faulty subsystem. This information should be gathered from physical inspection of the disassembled gearbox. The number of columns in this data file should be equal to number of subsystems in the gearbox and the number of rows should correspond to the number of feature vectors listed in the dialog item **Number of Feature Vectors**. The sequence in which the subsystems should appear in

columns is listed in the file SEQUENCE.OUT. Many times, subsystem numbers and column numbers in this file will not correspond. For example, targets associated with Subsystem 1 may internally be represented in DAG as column 3. Therefore, before constructing this file, the User needs to know the sequence in which subsystems are to be listed in the target file. This sequence information is listed by DAG in the SEQUENCE.OUT file. This file is created after the user presses the Ok Button in the dialog box. A dialog box appears instructing the user to check the file SEQUENCE.OUT. At this time, the user should open this file using any standard text editor (such as NOTEPAD) and make sure the targets listed in the subsystem file correspond to the correct subsystem. In the subsystem target file, enter a 0 to represent the corresponding subsystem (column) and feature vector (row) represent a normal subsystem, and 1 for faulty subsystem for that particular feature vector. Example: For OH58A gearbox (in examples sub-directory), the file SUBSYS.TAR lists the targets for Test No. 1. There are nine feature vectors in this test representing nine days, and three subsystems. The sequence in which these subsystems are created is listed in the file SEQUENCE .OUT.

Component Targets File Name

Data files containing 0 and 1 to represent a normal or faulty component. This information should be gathered from physical inspection of the individual components in disassembled gearbox. The number of columns in this data file should be equal to number of components in the gearbox and the number of rows should correspond to the number of feature vectors listed in the dialog item **Number of Feature Vectors**. The sequence in which the components should appear in the columns is listed in the file SEQUENCE.OUT. In the present design of DAG, the user does not information on the internal representation of the component numbers. For example, a Sun Gear in a gearbox could be the third component created. As such, this gear is internally assigned column three for component targets. Since this information is usually not available to the user, it is listed in the file SEQUENCE.OUT. This file is created after the user presses the Ok Button in the dialog box. A dialog box appears instructing the user to check the file SEQUENCE.OUT. At this time, the user should open this file using any standard text editor (such as NOTEPAD) and make sure the targets listed in the component file correspond to the correct components. In the component target file, enter a 0 to represent the corresponding component (column) and feature vector (row) represent a normal component, and 1 for faulty component for that particular feature vector. Example: For OH58A gearbox (in examples sub-directory), the file COMPS.TAR lists the targets for Test No. 1. There are nine feature vectors in this test representing nine days, and thirteen components. The sequence in which these components are created is listed in the file SEQUENCE .OUT.

Number of Training Iterations

Enter the total number of sweeps the training algorithm will run through the data set while training. Example: A value of 10 listed in this dialog item will make the training algorithm sweep through the batch of 9 feature vectors for Test No. 1 for OH58A gearbox ten times. For each sweep, the error between the outputs of SBCN and target values listed in the SUBSYS.TAR and COMPS.TAR files is computed, and the influence values adjusted to reduce the error value. A recommended iteration number for training is 1000.

Minimum Error to Achieve

Enter the minimum value of error between the outputs of SBCN and target values listed in the file SUBSYS.TAR and COMPS.TAR that is to be achieved. The same error value is used for both levels of SBCN. Example: a 0 value of minimum error will make the training algorithm sweep through the training data until the error is reduced to zero (or the **Number of Training Iterations** exceeds the specified number). A recommended value for minimum

value is 0.1.

Learning Rate

Enter the learning rate for adjusting the influences. Example: a 0.1 for learning rate adjusts the influences of SBCN proportional to 0.1 for each training iteration. Small values of learning rate (between 0.0001 and 0.01) are recommended.

See Also: [Supervised Training of SBCN](#)

3.1.6.7 Show Color Coded Results command (Diagnosis menu)

Use this command to see the faulty component isolation results from the second sub-section of SBCN in color coded format. These results must be first generated using Fault Isolation Only command before they can be viewed.

See Also: [Full Diagnosis](#)
 [Fault Detection Only](#)
 [Flagging Only](#)
 [Fault Isolation Only](#)

3.1.6.8 Make Fault Detection Independent command (Diagnosis menu)

Use this command to separate the outputs of Fault Detection Network and SBCN. By default, the outputs of Fault Detection Network (0 or 1) are multiplied with the outputs of SBCN. Clicking on this menu item avoids this multiplication. The user can compute the outputs of SBCN independent of the Fault Detection Network using this command.

See Also: [Make SBCN Levels Independent](#)
 [Full Diagnosis](#)
 [Fault Detection Only](#)
 [Fault Isolation Only](#)

3.1.6.9 Make SBCN Levels Independent command (Diagnosis menu)

Use this command to separate the outputs of Level 1 (Subsystem Isolation Level) and Level 2 (Component Isolation Level). By default, the outputs of Level 1 (values between 0 and 1) are multiplied with the outputs of Level 2 of SBCN. Clicking on this menu item avoids this multiplication. The user can compute the outputs of SBCN independent of each level using this command.

See Also: [Make Fault Detection independent](#)
 [Full Diagnosis](#)
 [Fault Detection Only](#)
 [Fault Isolation Only](#)

3.1.7 OPTIONS MENU COMMANDS

The Options menu offers the following commands:

<u>Adjust Detection Thresholds</u>	Allows the user to adjust the previously computed fault detection thresholds for sensors.
<u>Compute Detection Thresholds</u>	Computes fault detection thresholds for each sensor using the normal data.
<u>Adjust Flagging Threshold</u>	Allows the user to adjust a single flagging threshold which is common to all vibration features from all the sensors.
<u>Information of Selection</u>	Displays a dialog box with information on the currently selected component icon.
<u>Button Bar</u>	Displays or turns off the component toolbox.
<u>User Setup</u>	Allows user to setup defaults on help levels, component dialog box control, etc.

3.1.7.1 *Adjust Detection Thresholds command (Options menu)*

Use this command to adjust fault detection thresholds. Displays a Detection Threshold Dialog box which allows the user to adjust these thresholds.

The thresholds must be computed using the Compute Detection Thresholds command before they can be adjusted.

Shortcuts

Toolbar: 

See Also: Detection Threshold Dialog Box
Compute Detection Thresholds

3.1.7.2 *Compute Detection Thresholds command (Options menu)*

Use this command to compute fault detection thresholds for each sensor in the gearbox using the data from the normal file entered in the Sensor Dialog box. Displays a Detection Threshold Dialog box which allows the user to view/adjust these thresholds.

See Also: Detection Threshold Dialog Box
Sensor Dialog box

3.1.7.3 *Adjust Flagging Threshold command (Options menu)*

Use this command to adjust a single flagging threshold which is common to all vibration features from all the sensors. This threshold has a value between 0 and 1. A threshold value of 0 would

result in every feature after the first feature (which is assumed to be normal) to be categorized as abnormal. On the other hand, a value of 1 for the threshold will categorize all the features as normal. This command displays a Detection Threshold Dialog box which allows the user to adjust this thresholds. The default value for this threshold is 0.1.

See Also: Detection Threshold Dialog Box
 Adjust Detection Thresholds
 Compute Detection Thresholds

3.1.7.4 Detection Threshold Dialog Box

The following options allow you to adjust the fault detection thresholds for each sensor:

Sensor No.

This is an internal number created by DAG for the sensor. Each sensor can be identified by this number. This number appears in the Sensor Dialog box

Horizontal Scroll Bar

This scroll bar can be used to adjust the fault detection threshold. The scroll bar represents the length of the interval between lower and upper values displayed at the top left hand side and top right hand side of this scroll, respectively. To adjust the threshold, click on the left and right arrows. The current value of the threshold is displayed in the text box below this scroll bar.

Current Threshold

Displays the current value of the threshold.

Previous

Displays information on the sensor preceding the current sensor. The sequence in which the sensors are arranged is internal to DAG and cannot be modified. But this sequence is usually corresponds to the sequence in which they are created.

Next

Displays information on the sensor following the current sensor. The sequence in which the sensors are arranged is internal to DAG and cannot be modified. But this sequence is usually corresponds to the sequence in which they are created.

Ok

Closes the Detection Threshold Dialog Box. Saves the changes made by the user.

Cancel

Closes the Detection Threshold Dialog Box. Changes made by the user are not saved.

3.1.7.5 Information on Selection command (Options menu)

Use this command to displays a Gear Dialog box, Bearing Dialog box, Shaft Dialog box, or Sensor Dialog box with information on the currently selected component icon. A selected component icon is marked by four small square at its four corners.

See Also: Gear Dialog box
 Bearing Dialog box
 Shaft Dialog box
 Sensor Dialog box

3.1.7.6 Button Bar command (Options menu)

Use this command to display or turn off the Button Bar Dialog Box. This dialog box has shortcut buttons for Create: Gear, Bearing, Shaft, and Sensor, and Link: Connect, and Disconnect menu items

Shortcuts

Toolbar: 

See Also: Button Bar Dialog Box

3.1.7.7 User Setup command (Options menu)

Use this command to setup defaults on help levels, component dialog box control, and results display. A User Set Dialog Box appears on the screen where the user can select the defaults.

See Also: User Setup Dialog Box

3.1.7.8 User Setup Dialog Box

The following options allow you to setup the defaults on:

Show Dialog Boxes on Creation for

If the square box adjacent to item Gears is checked, then every time a gear component is created using the menu item User Setup Dialog Box then the Gear Dialog box appears at the time of creation. Similarly if other boxes in this group are checked, the dialog boxes associated with these components appear at the time of creation. If the boxes are unchecked, the process of creating the components becomes faster, but the user has to make sure that all the information for each component is entered at a later stage before diagnosis is performed. Information about components can be entered at a later stage by clicking the right mouse button on top of the component icon and using the dialog box that appears to enter new information.

Help Options

If the square box associated with Help Level 1 is checked, ALL messages, including help, warnings, etc., will appear on screen to help the user when he commits errors. Help Level 4 provides only the most important messages such as warnings.

Show Button Bar on Start Up

Displays the Button Bar when DAG is started.

Always Show Results in View Mode

Displays fault isolation results in view mode as they would appear when printed.

3.1.8 HELP MENU COMMANDS

The Help menu offers the following commands, which provide you assistance with this application:

<u>C</u> ontents	Displays the table of contents for help topics
<u>S</u> earch for Help On	Allows user to search for a specific help topic using clicking the mouse on the specific item.
<u>T</u> utorial	Explains the five step procedure for performing gearbox diagnosis with DAG.
<u>A</u> bout DAG	Displays the version number of DAG

3.1.8.1 Contents command (Help menu)

Use this command to display the opening screen of Help. From the opening screen, you can jump to step-by-step instructions for using DAG and various types of reference information.

Once you open Help, you can click the Contents button whenever you want to return to the opening screen.

3.1.8.2 Search for Help On

Use this Help command to obtain help on specific items of DAG. When you choose the Toolbar's Context Help button, the mouse pointer will change to an arrow and question mark. Then click somewhere in the DAG window, such as another Toolbar button. The Help topic will be shown for the item you clicked.

Shortcuts

Toolbar:



3.1.8.3 Tutorial

Use this Help command to obtain help on the Five Steps to Gearbox Diagnosis described in this Chapter.

3.1.8.4 About command (Help menu)

Use this command to display information on the authors of the DAG software as well as the funding source for developing this software.

3.1.9 TITLE BAR

The title bar is located along the top of a window. It contains the name of the application or dialog box. To move the window, drag the title bar. Note: You can also move dialog boxes by dragging their title bars.

A title bar may contain the following elements:

- Application Control-menu button
- Document Control-menu button
- Maximize button
- Minimize button
- Name of the application
- Name of the document
- Restore button

3.1.9.1 *Size command (System menu)*

Use this command to display a four-headed arrow so you can size the active window with the arrow keys.

After the pointer changes to the four-headed arrow:

1. Press one of the DIRECTION keys (left, right, up, or down arrow key) to move the pointer to the border you want to move.
2. Press a DIRECTION key to move the border.
3. Press ENTER when the window is the size you want.

Note: This command is unavailable if you maximize the window.

Shortcut

Mouse: Drag the size bars at the corners or edges of the window.

3.1.9.2 *Move command (Control menu)*

Use this command to display a four-headed arrow so you can move the active window or dialog box with the arrow keys.

Note: This command is unavailable if you maximize the window.

Shortcut

Keys: CTRL+F7

3.1.9.3 *Minimize command (application Control menu)*

Use this command to reduce the DAG window to an icon.

Shortcut

Mouse: Click the minimize icon on the title bar.
Keys: ALT+F9

3.1.9.4 Maximize command (System menu)

Use this command to enlarge the active window to fill the available space.

Shortcut

Mouse: Click the maximize icon on the title bar, or double-click the title bar.
Keys: CTRL+F10 enlarges a document window.

3.1.9.5 Next Window command (document Control menu)

Use this command to switch to the next open document window. DAG determines which window is next according to the order in which you opened the windows. Not implemented in DAG.

Shortcut

Keys: CTRL+F6

3.1.9.6 Previous Window command (document Control menu)

Use this command to switch to the previous open document window. DAG determines which window is previous according to the order in which you opened the windows. Not implemented in DAG.

Shortcut

Keys: SHIFT+CTRL+F6

3.1.9.7 Close command (Control menus)

Use this command to close the active window or dialog box.

Double-clicking a Control-menu box is the same as choosing the Close command.



Note: If you have multiple windows open for a single document, the Close command on the document Control menu closes only one window at a time. You can close all windows at once with the Close command on the File menu.

Shortcuts

Keys: ALT+F4 closes the DAG window or dialog box

3.1.10 QUIT MENU COMMANDS







The Quit menu exists the DAG application. Unsaved files may be lost.

Shortcuts

Keys: ALT+F4 closes the DAG application

3.2 BUTTON BAR DIALOG BOX

Button bar is dialog box with icons that act as shortcuts for the menu items Create: Gear, Bearing, Shaft, and Sensor, and Link: Connect, and Disconnect. It can be used instead of the menu items in Create and Link. The icons in the toolbar perform the following tasks:

Icon	Function
	Creates a gear icon. Performs the same task as menu item Create-Gear.
	Creates a bearing icon. Performs the same task as menu item Create-Bearing.
	Creates a shaft icon. Performs the same task as menu item Create-Shaft.
	Creates a sensor icon. Performs the same task as menu item Create-Sensor.
	Allows user to connect two icons to represent a physical connection. Performs the same task as menu item Link-Connect.
	Allows user to disconnect two icons. Performs the same task as menu item Link-Disconnect.

Close Button - Closes the toolbar. It can be reopened by using menu item Options-Toolbar.

See Also:

[Create Gear](#)

[Create Bearing](#)

[Create Shaft](#)

[Create Sensor](#)



















[Link Connect](#)

[Link Disconnect](#)

3.3 TOOLBAR COMMAND

Use this command to display and hide the Toolbar, which includes buttons for some of the most common commands in DAG, such as File Open. A check mark appears next to the menu item when the Toolbar is displayed.

Toolbar refers to the small buttons that are displayed across the top of the application window, below the menu bar. The Toolbar provides quick mouse access to many tools used in DAG,

Click	To
	Closes Current file and opens a new gearbox file. Same as menu item File-New.
	Opens an existing gearbox file. Same as menu item File-Open. DAG displays the Open dialog box, in which you can locate and open the desired file.
	Save the gearbox file without prompting. Same as menu item File-Save. If you have not named the document, DAG displays the Save As dialog box.
	Change test data files, normal files, etc. Same as menu item File-Change Test Sets.
	Deletes the selected component icon from DAG. A selected component icon has four small solid rectangles at its four corners. Once the component is deleted, it cannot be retrieved.
	Copy the selected component icon to the clipboard. Not implemented.
	Insert the contents of the clipboard into DAG Not implemented.
	Prints diagnostic results. Same as menu item File-Print Results.
	Display diagnostic results as they would appear on paper when printed. Displays fault detection and diagnosis results in view mode. Same as menu item File-View Results.
	For defining a primary vibration flow path. Same as menu item Link-Define Primary Vibration Path.
	Perform fault detection, flagging and fault isolation. Same as menu item Diagnosis-Full Diagnosis.
	Perform only fault detection. Same as menu item Diagnosis-Fault Detection Only.
	Perform fault isolation only. Same as menu item Diagnosis-Fault Isolation Only.
	Modify structural influences. Same as menu item Influences-Modify Featural influences.
	Modify featural influences Same as menu item Influences-Modify Featural influences.
	Adjust the fault detection thresholds for each sensor. Same as menu item Options-Adjust Thresholds.
	Close or open the button bar. Same as menu item Options-Button Bar.
	Provides help on any item which is the user clicks after clicking this button.

3.4 ACCELERATOR KEYS

Accelerator keys provide yet another shortcut to access menu items. These keys which appear adjacent to the menu item (e.g., File- Open F12) are keys on the keyboard (F12) that can be pressed to give a command to DAG. Pressing these keys is equivalent to selecting the appropriate menu item. Here are a few examples of accelerators keys:

F12	File New - Closes Current file and opens a new gearbox file. Same as menu item File-New.
F10	File Open - Opens an existing gearbox file. Same as menu item File-Open
F2	File Save - Save the gearbox file without prompting. Same as menu item File-Save.
CTRL+I	Information on Selection - Displays a gear/bearing/shaft/sensor dialog box with information on the component which is selected. CTRL is the Control Key on the keyboard. To press CTRL+I, first press and hold down Control Key and then press the alphabet key I.

3.5 STATUS BAR COMMAND

Status Bar describes the action to be executed by the selected menu item or depressed toolbar button, and keyboard latch state. A check mark appears next to the menu item when the Status Bar is displayed.

Status Bar

The status bar is displayed at the bottom of the DAG window. Here information on the tasks DAG is performing in the background is provided. This information includes messages for fault detection, flagging, fault isolation, etc.

The left area of the status bar also provides information about each menu item, when the menu item is highlighted. To highlight a menu item, click on the top menu item (e.g., File, Connect, Link, etc.) and use arrow keys on keyboard to highlight a menu item. Menu items can also be highlighted by clicking and holding the left mouse button on top of the menu item. Release the mouse button on top of the menu item if you want the command executed, or release it in the DAG window, if you don't want the command executed. This area similarly shows messages that describe the actions of toolbar buttons as you depress them, before releasing them. If after viewing the description of the toolbar button command you wish not to execute the command, then release the mouse button while the pointer is off the toolbar button.

The right areas of the status bar indicate which of the following keys are latched down:

Indicator	Description
CAP	The Caps Lock key is latched down.

NUM	The Num Lock key is latched down.
SCRL	The Scroll Lock key is latched down.

4. CONSTRUCTING THE GEARBOX STRUCTURE

In order to perform fault diagnosis for a gearbox, DAG requires information on the number of gears, bearings, shafts, and sensors and their structural connections. This chapter explains the procedure for constructing the gearbox structure in DAG.

Creating a Gear

Creating a Bearing

Creating a Shaft

Creating a Sensor

Sensor Data File Format

Modifying Information on Components

Creating the Rest of the Gearbox

Moving the Components

Connecting the Components

Avoiding Intersecting Connection Lines

Drawing Horizontal or Vertical Connection Lines

Disconnecting Components

4.1 CREATING A GEAR

To represent the gearbox component gear, it has to first created in DAG. A gear can be created by two different methods: (1) using the shortcut toolbar, or (2) by selecting the menu item Create-Gear. The faster method for creating a gear is to click the left mouse button on the gear icon in the toolbar. If the tool bar is not visible, then select the menu item Options-Button Bar.

A gear dialog box for setting various properties (e.g., gear name, gear teeth, gear diameter) of the gear appears on the screen. The Gear Number is an internal number used by DAG to identify the component. Do not modify it. The two compulsory items that must be entered in the dialog are Gearbox Name and Gear Name. The gearbox name entered when the first component is created will be copied to all the subsequent components. Others items in the dialog box such as the Gear Diameter, Number of Teeth, Helix Angle are optional. Since the current version of DAG uses a simplified model of vibration attenuation, the optional items are not used.

Click on the Ok Button at the bottom of the dialog box to create the component. Clicking on Cancel Button aborts the creation of gear.

If the Ok Button is clicked, an icon with a picture of a gear on will appear at the top left hand corner of the window, with the name of the gear appearing in short form at the bottom of the icon (e.g., Spiral Bevel Pinion's short form appears as SBP). This gear icon in DAG represents the physical gear in the gearbox.

4.2 CREATING A BEARING

To create a bearing, select menu item Create-Bearing. Note that the faster method of creating a bearing is clicking the left mouse button on the bearing icon in the toolbar. A bearing dialog box for setting the properties of the bearing will appear. The Bearing Number in this dialog box is an internal number used by DAG to identify the component. Do not modify it. The compulsory items that must be entered in this dialog box are Gearbox Name and Bearing Name. (Note: The correct gearbox name automatically appears in the bearing dialog box if it has been entered correctly in the first component that is created. It need not be modified if correct.)

Click on Ok Button to create the bearing or Cancel to abort. If the Ok Button is clicked, an icon with a picture of a bearing on will appear at the top left hand corner of the window, with the name of the bearing appearing in short form at the bottom of the icon (e.g., Triplex Bearing's short form appears as TB). This bearing icon in DAG represents the physical bearing in the gearbox.

4.3 CREATING A SHAFT

To create a shaft, select menu item Create-Shaft. Note that the faster method of creating a shaft is clicking the left mouse button on the shaft icon in the toolbar. A shaft dialog box for setting the properties of the shaft will appear. The Shaft Number is an internal number used by DAG to identify the component. Do not modify it. The compulsory items that must be entered in this dialog box are Gearbox Name (if empty) and Shaft Name

Click on Ok Button to create the shaft or Cancel to abort. If the Ok Button is clicked, an icon with a picture of a shaft on will appear at the top left hand corner of the window, with the name of the shaft appearing in short form at the bottom of the icon (e.g., Main Shaft's short form appears as MS). This shaft icon in DAG represents the physical shaft in the gearbox.

4.4 CREATING A SENSOR

To create a sensor (accelerometer), select menu item Create-Sensor. Note that the faster method of creating a sensor is clicking the left mouse button on the sensor icon in the toolbar.

A Sensor dialog box appears on the screen. The Sensor Number is an internal number used by DAG to identify the component. Do not modify it. All the items in this dialog box must be filled for fault diagnosis to work properly.

See Sensor dialog box for examples on each item in the dialog box.

Click on Ok Button to create the sensor or Cancel to abort. If the Ok Button is clicked, an icon with a picture of sensor on will appear at the top left hand corner of the window, with the name of the sensor appearing in short form at the bottom of the icon (e.g., Spiral Bevel Pinion's short form appears as SBP). This sensor icon in DAG represents the physical sensor mounted on the gearbox.

4.5 MODIFYING INFORMATION ON COMPONENTS

After a component is created, the user can view or modify the component information such as its name by clicking the right mouse button on top of the component. For example, if the right mouse button is clicked on a gear icon, a gear dialog box appears with the original information entered by the user. This information can be modified by the user. To save the modification and close the dialog box, click the left mouse button the Ok. To close the dialog without saving modifications, click the left mouse button on Cancel.

A second method to obtain information on a selected component is to use the menu item Options-Information on Selection. A selected component is one which has four small rectangles at its four corners.

A shortcut to obtaining information on a selected component icon is to use accelerator key CTRL+I.

4.6 CREATING THE REST OF THE GEARBOX

To create the rest of the gearbox, create the required number of gears, bearings, shafts and sensors according the procedure described in CREATING A GEAR, CREATING A BEARING, CREATING A SHAFT, and CREATING A SENSOR, respectively.

4.7 MOVING THE COMPONENT ICONS

In order to place the component icons at the position of users choice, the component icons can be dragged and dropped at the desired position. In order to move a component icon, move the mouse-pointer to top of the icon, and click and hold down the left mouse button. Then move the mouse to the desired position in the DAG window and release the left mouse button. This will move the component icon from its original position to the new position. (Note: Components icons that are connected to other icons cannot be moved unless they are disconnected. See CONNECTING THE COMPONENT ICONS and DISCONNECTING THE COMPONENT ICONS for more information.)

4.8 CONNECTING THE COMPONENTS

Once all the gearbox components are created, they should be connected in DAG to represent the structural connections physically present among the components in the gearbox. For example, two physically meshing gears in the gearbox are to be connected in DAG by drawing a line between these the two component icons to represent the mesh.

Two components icons in DAG can be connected in two different methods: (1) by clicking the left mouse button on the link button in the shortcut toolbar, or (2) by selecting menu item Link-Connect. While shortcut toolbar is faster, both methods produce the same results.

After clicking on the link button in toolbar or selecting menu item Link-Connect, click the left mouse button on top of the first of the two component icons to be connected. After clicking on top of the component icon, a line appear from this component to the current position of the mouse pointer. Move the mouse-pointer onto the second component icon that you want to connect to, and click the left mouse button again. This will draw a line between the two component icons to represent the physical connection between the two components in gearbox.

4.9 AVOIDING INTERSECTING CONNECTION LINES

To avoid confusion due to numerous intersecting connection lines, DAG allows the connection lines to be drawn around other components. To do this, select menu item Link-Connect (or click on the link button in the toolbar) and click the left mouse button on top of the first component to be connected. As before, a line will appear from this component to the mouse-pointer. Move the mouse-pointer to any other part of the DAG window (away from the components you want to avoid) and click the left mouse button again. A line will be drawn from the first component to the position where the mouse was clicked. A new line will also appear from the mouse click position to the current mouse-pointer. Continue making your way around the components you want to avoid and towards the second component that you want to connect to by clicking the left mouse button in different positions in the DAG window. To end complete this connection, click the left mouse button on top of the second component icon.

4.10 DRAWING HORIZONTAL OR VERTICAL CONNECTION LINES

Note that connection lines can be drawn either horizontal or vertical by pressing and holding down the Shift key when the connection lines are being constructed. Complete connecting all the component icons in DAG to represent all the physical connections in the gearbox.

4.11 DISCONNECTING COMPONENTS

If a mistake was made in connecting two component icons, complete connecting the component icons. Then to disconnect them, select menu item Link-Disconnect (or click the left mouse button on the disconnect button in the shortcut toolbar). Then click the left mouse button on the first component icon, and then again on the second component icon. The line connecting the two components will be erased, indicating that they are disconnected.

5. STRUCTURAL INFLUENCES

In DAG, Structural Influences represent the relation between component faults and average sensor readings. They define through the fuzzy influences (Definite, High, Medium, Low and Nil), the effect a component fault is expected to have on the overall vibration level of various gearbox sensors. For example, an influence of high between a component and a sensor indicates that the possibility of the sensor showing abnormal vibration levels due to the fault is high.

This chapter covers the following topics:

- Defining Vibration Paths
- Deleting Vibration Paths
- Viewing and Deleting Vibration Paths
- Generating Structural Influences
- Modifying Structural Influences
- Defining Subsystems

5.1 DEFINING VIBRATION PATHS

Although structural influences will be generated automatically by DAG, the user is required to define the vibration flow paths in the gearbox on which the structural influences are based. In order to define the vibration flow path, some expertise on the most important paths in the gearbox which contribute to the vibration transfer from the components to the sensor is required. An example of vibration flow path would be the path from a meshing gear through its supporting shaft and bearing to the sensor. This path, once defined in DAG, will then be used by its diagnostic knowledge extraction routines to assign structural influences to relate component faults to sensor readings. Constructing a comprehensive set of vibration paths is important since the quality of diagnosis (by the Structure-Based Connectionist Network) critically depends on the vibration paths.

The general guidelines for constructing vibration flow paths are:

- ⇒ Flow paths always start with a sensor.
- ⇒ The flow path usually end with a bearing as its last component.
- ⇒ A physical connection (a connection line in DAG) must exist between two components for a vibration flow path to exist between them.
- ⇒ The sequence of components in the flow path is important. The path must be defined to reflect the fact that components closer to the sensor will have greater affect on the sensor than the components farther away. Hence, the number of components between a sensor-component pair should be inversely proportional the strength of vibration signal registered by the sensor.
- ⇒ Flow paths through the gearbox housing are neglected. If the user believes that a flow paths passes through the housing, use menu item Influences-Modify Structural Influences to change the influences generated by DAG to reflect this path.

⇒ Separate flow paths must be defined when at least one component/sensor in the flow path is different.

To construct a vibration flow path, select menu item Link-Define Vibration Path (or click on the button corresponding to vibration paths in the Button Bar (see BUTTONBAR in KNOWING THE INTERFACE: MENU, TOOLBAR)). First click the left mouse button on top of the sensor icon. (Note: As the vibration path defines vibration flow from components to a sensor, the first icon that is clicked on must be a sensor.) A thick line will appear on the DAG window from the clicked sensor to the current mouse-pointer position. Click the left mouse button on the next component in the vibration flow path. A thick line will be drawn between the sensor and the component to represent vibration flow from this component to the sensor. Continue clicking on other components in the flow path in the sequence they are connected. (Note that a physical connection in form of connection line must exist between two components for vibration flow to be defined between them (See 'CONNECTING THE COMPONENT ICONS' for more information.)) To end the vibration flow path, double click the left mouse button on top of the last components in the path. All the thick lines will be erased from the screen, but DAG creates an internal data structure to represent the vibration flow path.

5.2 DELETING VIBRATION PATHS

If the user makes a mistake in constructing a vibration flow path, complete constructing the path. Then select menu item Link-Delete Vibration Path. First, click the left mouse button on the sensor in the vibration path and then on the last component icon in the path. If a path exists between these two icons it will be automatically deleted.

5.3 VIEWING AND DELETING VIBRATION PATHS

A more easier method for viewing and deleting vibration paths is through menu item Link-Show All Vibration Paths. On selecting this menu item, the first vibration flow path will be drawn in the DAG window and a dialog box will appear at the bottom of the DAG window. By clicking the Previous and Next Buttons in the dialog box, the previous and the next vibration paths in the gearbox can be viewed, respectively. To delete the currently displayed vibration path, click on the Delete Button in the dialog box. To quit viewing the vibration paths, click the mouse on the Ok button in the dialog box.

5.4 GENERATING STRUCTURAL INFLUENCES

After all the vibration flow paths, select the menu item Influences-Generate Structural Influences. DAG will use the vibration paths defined by the user to generate the structural influences. Note that previous modifications made by the user to the influences table will be lost when this option is selected. Use menu item Influences-Modify Structural Influences to modify previously generated structural influences.

After the structural influences are generated, they are displayed in the structural Influence Matrix dialog box. In this dialog box, a structural influence table is displayed at the top with buttons at the bottom of the dialog box. The rows in the structural influence table represent the gearbox sensors while the columns represent the gearbox components. Both row and columns are titled with the names of the sensors and component respectively. In the second row of this table information on the subsystems each of the component belongs to is listed. See **DEFINING SUBSYSTEMS** for more information on how to assign a component to a subsystem. The influences represented in the influence table refer to:

Influence Character	Fuzzy Influence	Influence Range
D	DEFINITE	(0.9 - 1.0)
H	HIGH	(0.6 - 0.9)
M	MEDIUM	(0.4 - 0.6)
L	LOW	(0.1 - 0.4)
-	NIL	(0.0 - 0.1)

DAG allows the user to modify the structural influences. These changes can be made in the Structural Influence Matrix dialog box. For more information on modifying the influences see **MODIFYING STRUCTURAL INFLUENCES**. After viewing the structural influences, click on the Ok Button to save the any changes made to the table and quit, or Cancel Button to abort changes.

5.5 MODIFYING STRUCTURAL INFLUENCES

If the user wants to adjust structural influences to improve diagnostic results, or study the effect of variations of influences on the results, DAG allows the user to modify the structural influences through its menu item Influence-Modify Structural Influences. Modifying structural influences involves changing the fuzzy influence characters (see **GENERATING STRUCTURAL INFLUENCES**) in the structural influence table.

In order to modify the structural influences, select the menu item Influences-Modify Structural Influences. Note that a shortcut for this menu item is to click the left mouse button on the modify structural influences button in the Buttonbar (see **BUTTONBAR** in **KNOWING THE INTERFACE: MENU, TOOLBAR**). A Structural Influence Matrix Dialog Box appears on the screen. In this dialog box, a structural influence table is displayed at the top with buttons at the bottom of the dialog box. The rows in the structural influence table represent the gearbox sensors while the columns represent the gearbox components. Both row and columns are titled with the names of the sensors and component respectively. In the second row of this table information on the subsystems each of the component belongs to is listed. See **DEFINING SUBSYSTEMS** for more information on how to assign a component to a subsystem.

The influence table contains fuzzy influence characters D, H, M, L, and - to represent the DEFINITE, HIGH, MEDIUM, LOW, and NIL influences respectively (see **GENERATING STRUCTURAL INFLUENCES**). To modify these influence characters, click the left mouse

button in the cell with the influence character in it. The influence character is copied to the text box at the bottom left hand part of the dialog box. Enter the new character that you want the influence to be changed to. Note that the characters entered by the user are not case-sensitive. However, these characters must belong to the set D, H, M, L, and - to be valid. Click the left mouse button on the Update Button adjacent to the text box. The influence character will be copied back to its cell, indicating that the change has been made to the table.

After making all the desired modification, click on the Ok Button to save the changes and quit, or Cancel Button to abort changes. Note that the procedure described above can be also be applied to change the influences when the structural influence matrix dialog box appears in response to the user selecting the menu item Influences-Generate Structural Influences.

5.6 DEFINING SUBSYSTEMS

Diagnosis in DAG is performed by two different sub-sections of the Structure-Based Connectionist Network (SBCN). While in the first sub-section, faulty subsystems are isolated, in the second sub-section faulty component are isolated. In order to perform fault subsystem isolation, DAG requires the user to group the gearbox components into subsystems. Components can be grouped into subsystems using the Structural Influence Matrix Dialog Box.

To define subsystems, select menu item Influences-Modify Structural Influences. The shortcut to this menu item is the Modify Structural Influence button in the Buttonbar (see BUTTONBAR in KNOWING THE INTERFACE: MENU, TOOLBAR). A Structural Influence Matrix Dialog Box appears on the screen. In this dialog box, a structural influence table is displayed at the top with buttons at the bottom of the dialog box. The rows in the structural influence table represent the gearbox sensors while the columns represent the gearbox components. Both row and columns are titled with the names of the sensors and component respectively. In the second row of this table information on the subsystems each of the component belongs to is listed. Initially only the characters 'SS' appear in each of the columns in this row. This is because the components are not assigned to any subsystem yet.

To form a group of components to define a subsystem, click the left mouse button the Define Subsystem Button at the bottom of the dialog box. Then click the left mouse button on all the component names in the influence table (or the corresponding columns) that belong to this subsystems. The 'SS' characters in the second row associated with the clicked components will change to 'SS 1' to indicate that all these components belong to Subsystem No. 1. (Caution should be employed in defining subsystems, as subsystems cannot be undone once they are formed and saved by clicking the Ok Button.)

To end defining a subsystem, click on the End Subsystem Button at the bottom of the dialog box.

After grouping all the component into subsystems, click on the Ok Button to save the changes and quit, or Cancel Button to abort changes.

6. FEATURAL INFLUENCES

In DAG, while the structural influences are generated automatically by DAG's diagnostic knowledge extraction routines using the vibration flow paths, the featural influences have be manually entered into DAG. The featural influences which represent the relation between individual vibration features and component faults can be constructed using the menu item Influences-Add Featural Influences. Note that featural influences must be generated only after all the components in the gearbox are created (see CONSTRUCTING THE GEARBOX STRUCTURE).

Adding Features and Their Influences
Defining Groups
Modifying the Features and Their Influences
Standard Featural Influences

6.1 ADDING FEATURES AND THEIR INFLUENCES

Select menu item Influences-Add Featural Influences. A dialog box with a featural Influence table and some buttons at the bottom will appear on the screen. In this table, the total number of rows corresponds to the maximum number of features listed in all the sensors in the gearbox (see CREATING A SENSOR in CONSTRUCTING THE GEARBOX STRUCTURE). If the number of features listed for a sensor is not the same, use only the features common to all sensors for diagnosis. The number of columns in the table corresponds to the number of components in gearbox with each column titled by the component name.

To enter a feature, click the left mouse button in the second row, third column cell with the text 'INSERT' in it. This text will be copied into the text box at the bottom left corner above the Help button in the dialog box. Enter the name of the feature into the text box and click on the Update Value Button on its right. The feature name will be copied from the text box into the second row third column cell in the table. Avoid using long names for features (recommended length of about 10 characters).

It should be noted that DAG will associate vibration features in the third column in the table in the order they appear to the columns in the sensor data file. Therefore, the sequence of features entered in this table MUST correspond to the sequence of features in the sensor data files (see SENSOR DATA FILE FORMAT in CONSTRUCTING THE GEARBOX STRUCTURE). For example, consider the four columns of data from the SENSOR DATA FILE FORMAT section in CONSTRUCTING THE GEARBOX STRUCTURE. If the first, second, third and fourth columns correspond to Skewness, Kurtosis, Crest Factor, and Peak to Peak features as:

Skewness	Kurtosis	Crest Factor	Peak to Peak
1.00	1.00	1.00	1.00
1.21	1.46	1.00	1.04
1.42	2.09	1.03	1.90
1.39	4.99	2.11	1.99
1.03	4.34	3.21	3.22
1.39	4.99	2.11	1.99
1.42	2.09	1.03	1.90

then, the first four features in third column of the Featural Influence Table must be Skewness, Kurtosis, Crest Factor, and Peak to Peak in that order.

After entering the feature name, its relation to the component faults must be entered by the user in the row corresponding to the feature. The relation between features and component faults is represented by the five fuzzy variables as:

Influence Character	Fuzzy Influence	Influence Range
D	DEFINITE	(0.9 - 1.0)
H	HIGH	(0.6 - 0.9)
M	MEDIUM	(0.4 - 0.6)
L	LOW	(0.1 - 0.4)
-	NIL	(0.0 - 0.1)

While a NIL represents no relation between feature and component fault, a DEFINITE indicates that the feature will be definitely affected by the component fault. General guidelines used to assign the featural influences are:

Relation Between	Assign Influence
Gear Features and Gears	HIGH
Bearing Features and Bearings	HIGH
General Features and Gears and Bearings	MEDIUM

Gear features in the above table include features such as Cepstrum and signal averaged features (processed at the gear meshing frequencies). Bearing features include Cepstrum (processed at the bearing rotational frequencies), Envelope Analysis Features (Envelope Base Energy, Envelope Tone Energy, etc.). General Features include Statistical Features such as Root Mean Square value, Skewness, Kurtosis, etc.

To enter the fuzzy variable to relate a feature to a component, click the left mouse button in the cell corresponding to the feature and component in the table. Then enter the influence characters D, H, M, L, or - in the text box at the bottom left corner of the dialog box and click the Update

Value Button. The fuzzy variable in the text box will be copied to the corresponding cell in the table. Note that the characters entered by the user are not case-sensitive. However, these characters must belong to the set D, H, M, L, and - to be valid. Similarly enter the rest of the fuzzy influences between feature and all the components in the gearbox. Remember that features also need to be grouped before they can be used for diagnosis. See DEFINING GROUPS in this chapter for more details.

After entering all featural influences click on the Ok Button to save changes and quit, or Cancel Button to abort changes.

6.2 DEFINING GROUPS

In order to perform abnormality-scaling of features, the Single Category-Based Classifier (SCBC) requires grouping information for the features. The grouping information indicates the features that belong in a group, such that when a component fault occurs the SCBC tries to achieve homogeneity in classification. For example, a group of features could be all those features related to a specific gear such as a sun gear. SCBC tries to maintain homogeneity in features in this group such that it tries to categorize all the features as normal or abnormal.

In order to form groups of features, click the left mouse button on the Define Group Button. Then click the left mouse button in all the rows associated with this group. Notice that the text in the second column of the table changes from 'Grp' to 'Grp 1' to indicate that the feature in the clicked row now belongs to Group No. 1 (Caution should be employed in defining groups, as grouping cannot be undone once they are defined and saved by clicking the Ok Button. Only method of undoing a grouping is to click the Cancel button in which case all the changes made since this dialog box appeared will be lost.)

To end the group click the left mouse button on the End Group Button. Features in the columns that were clicked will be categorized into one group. Click on Define Group Button again to define the next group.

After grouping all the features, click on the Ok Button to save changes or click on Cancel Button to abort changes.

6.3 MODIFYING THE FEATURES AND THEIR INFLUENCES

Once the features and their influences are defined, they can be modified by the user by selecting the menu item Influences-Modify Featural Influences. A dialog box with featural influence table and buttons at the bottom will appear on the screen. This dialog box is exactly the same one that appears when the user selects the menu item Influences-Add Featural influences. The only difference is that when the Modify Featural Influences menu item is selected, the featural influence table is filled with information previously entered by the user so that he could modify it.

To modify the feature names and their influences, click in the cell associated with them. The text (name or influence) is copied to the text box at the bottom of the table. Modify the name or

influences in this text box and click the adjacent Update Value Button modify it. For more details on modifying the table, see ADDING THE FEATURES AND THEIR INFLUENCES.

6.4 STANDARD FEATURAL INFLUENCES

As entering the influences for large number of features and components is a cumbersome task, it can be partly automated using the Standard Influences feature of DAG. Standard Influences is a list of features which the user hopes to use repeatedly. For example, if Skewness is a Feature that is used repeated for every gearbox analyzed by DAG, it can be entered into the a Standard Influence list for reuse. Every time the user enters Skewness as a feature in the third column in the featural influence table, DAG automatically searches the standard influences list, and if it finds the feature, it automatically assigns the influences associated with gear, bearings, and shafts in the influence table.

To add a feature to the Standard Influence list, first enter all the influences associated with the components. Then click the left mouse button in the row associated with feature, and then click the left mouse button on the Add to Standard List Button at the bottom of dialog box. DAG will search the row associated with the feature, and picks up on influence each for a gear, bearing, and a shaft and stores it in the Standard Influence List for future reuse.

To view the Standard Influence List, click left mouse button on the Show Standard List Button at the bottom of the dialog box. A new dialog box will appear which shows the features in the list and their influences on gears, bearing and shafts.

7. DIAGNOSIS AND RESULTS

In order to perform fault detection and diagnosis the following information is required:

Sensor Test and Normal Data Files	User must enter these in the Sensor Dialog Box
Structural Influences	DAG generates these based on user defined vibration Flow Paths.
Featural Influences	User must enter these using Menu item Diagnosis-Generate Featural Influences.

In this chapter, the following topics are discussed.

Performing Fault Detection, Flagging And Isolation

Performing Fault Detection

Performing Flagging

Performing Fault Isolation

Fault Detection Results

Viewing Fault Detection Results in View Mode

Printing Fault Detection Results in View Mode

Printing Fault Detection Results

Fault Isolation Results

Color Coded Format Mode

Viewing Fault Isolation Results in View Mode

Printing Fault Isolation Results in View Mode

Printing Fault Isolation Results

The Gearbox Structure

Viewing The Gearbox Structure in View Mode

Printing Gearbox Structure From View Mode

Printing The Gearbox Structure

The Influence Tables

Viewing The Influence Tables in View Mode

Printing The Influences From View Mode

Printing The Influence Tables

7.1 PERFORMING FAULT DETECTION, FLAGGING, AND ISOLATION

Once the three pieces of information required for fault detection and diagnosis are constructed, Fault Detection, Abnormality Scaling, and Fault Diagnosis can be simultaneously performed by selecting the menu item Diagnosis-Full Diagnosis.

The operation of full diagnosis might take up to 10 minutes depending on the number of features and complexity of gearbox. The following tasks are performed when this menu item is selected:

Fault Detection
Flagging
Fault Isolation

For more details on the algorithms for Fault Detection, Flagging and Fault Isolation, please refer to list of publications in the reference section of this user's guide.

7.1.1 PERFORMING FAULT DETECTION ONLY

Once the three pieces of information required for fault detection are constructed, Fault Detection, can be performed by selecting the menu item Diagnosis-Fault Detection Only. This operation can take up to 3 minutes depending on the number of features and sensors in the gearbox. The following tasks are performed when this menu item is selected:

Fault Detection by Fault Detection Network (FDN):

- The memory required to read the features in DAG is assigned.
- The data files are read.
- Fault detection Thresholds are computed using the normal data files.
- Fault Detection Networks are created, one for each sensor.
- Fault detection is performed.
- Adaptation of FDN's weights is performed at each step of fault detection.
- The results are displayed in text mode.

For more details on the algorithms for Fault Detection, Flagging, and Fault Isolation, please refer to list of publications in the reference section of the user's guide.

7.1.2 PERFORMING FLAGGING ONLY

Once the three pieces of information required for fault isolation are constructed, Flagging (Abnormality Scaling) can be performed by selecting the menu item Diagnosis-Flagging Only. This operation can take up to 3 minutes depending on the number of features and sensors in the gearbox. The following tasks are performed when this menu item is selected:

Flagging (Abnormality-Scaling) by Single Category-Based Classifier (SCBC):

- The memory required to read the features in DAG is assigned (if necessary).
- The data files are read (if necessary).
- SCBC Thresholds are computed using the normal data files.

SCBC's are created, one for each sensor.
Abnormality-Scaling is performed.
Adaptation of SCBC's weights is performed at each step of Scaling.
Abnormality-Scaling results are written in ASCII text format to a file.

For more details on the algorithms for Fault Detection, Flagging, and Fault Isolation, please refer to list of publications in the reference section of the user's guide.

7.1.3 PERFORMING FAULT ISOLATION ONLY

Once the three pieces of information required for fault isolation are constructed, Fault Isolation can be performed by selecting the menu item Diagnosis-Fault Isolation Only. This operation can take up to 2 minutes depending on the number of features and complexity of gearbox. The following tasks are performed when this menu item is selected:

Fault Diagnosis by Structure-Based Connectionist Network (SBCN):

- The memory required to read the features in DAG is assigned (if necessary).
- The data files are read (if necessary).
- Fault detection is performed (if necessary).
- Checks if Flagging (abnormality scaling) by SCBC was performed.
- Subsystem and Component Level SBCN's are created.
- Structural Influences are prepared.
- Featural Influences are prepared.
- Fault diagnosis is performed.
- Results are displayed in color coded format.

For more details on the algorithms for Fault Detection, Flagging, and Fault Isolation, please refer to list of publications in the reference section of the user's guide.

7.2 FAULT DETECTION RESULTS

After the Fault Detection Networks (FDNs) perform fault detection, the results are usually displayed in text mode. The following options lets you view and print these detection results:

- Viewing Fault Detection Results in View Mode
- Printing Fault Detection Results in View Mode
- Printing Fault Detection

7.2.1 VIEWING FAULT DETECTION RESULTS IN VIEW MODE

After the Fault Detection Networks (FDNs) perform fault detection, the results are displayed in text mode. The results appear in view mode (view mode displays results as they would be appear on paper when printed). Note that results will appear in full page mode initially and may be too small to see. Click the left mouse button on the button Zoom In at the top of screen. The results will be re-displayed on the screen in an enlarged format. Click on the same button to zoom in more into the results, while click on the Zoom Out Button to zoom out to full page mode.

The results from FDN would be titled

FAULT DETECTION NETWORKS: FAULT IDENTIFICATION RESULTS

Below this title, information regarding the number of sensors, components, number of feature vectors, etc. will appear. After this, a table of fault detection results appears. The rows in this table represent the feature vectors for each sample reading (days, patterns, or snapshots) and the columns represent the sensors. The first row of this table lists the abbreviated names of sensors (e.g., Sensor 1 abbreviated as S1). The next row lists the thresholds for each of these sensors computed using the normal data. The third row lists the maximum value of output (pre-thresholded) from each of the FDNs for each sensor (these are the maximum pre-thresholded values in the corresponding column). From fourth columns onwards, the fault detection results are included, with a 0 indicating that the features from the sensor are normal, while a 1 indicating an abnormal readings from that sensor. Each subsequent row lists the fault detection results for subsequent feature vector samples.

Both fault detection results from Fault Detection Networks (FDNs) and fault identification results from Structure-Based Connectionist Network (SBCN) can be printed using a printer installed in Windows 3.1. To print results, select menu item File-Print Results. A Print Dialog Box appears, wherein the user can select the pages to printed, and the number of copies to produce. Clicking the left mouse button on the Setup Button in the Print Dialog Box, a Printer Setup dialog box appears. In this dialog box the user can select the printer to be used, the orientation (portrait or landscape), paper size and source tray. A further Options Button in this dialog box allow the user to control the print intensity (light or dark) and dithering (coarse, fine, etc.).

After selecting the pages and copies in the Print Dialog Box, click the left mouse button on Ok to print the results. Click on Cancel Button to abort.

7.2.2 PRINTING RESULTS FROM VIEW MODE

Both fault detection and fault isolation results can be printed from the view mode. View mode is activated when the menu item File-View Results is selected. The results shown in this mode will appear exactly as they are printed on paper.

To print from view mode, click the left mouse button on the Print Button at the top left hand corner of the view window. A Print Dialog Box will appear. Clicking the left mouse button on the Ok Button will print the results, while clicking on Cancel will abort printing.

7.2.3 PRINTING RESULTS

Both fault detection results from Fault Detection Networks (FDNs) and fault identification results from Structure-Based Connectionist Network (SBCN) can be printed using a printer installed in Windows 3.1. To print results, select menu item File-Print Results. A Print Dialog Box appears, wherein the user can select the pages to printed, and the number of copies to produce. Clicking the left mouse button on the Setup Button in the Print Dialog Box, a Printer Setup dialog box appears. In this dialog box the user can select the printer to be used, the

orientation (portrait or landscape), paper size and source tray. A further Options Button in this dialog box allow the user to control the print intensity (light or dark) and dithering (coarse, fine, etc.).

After selecting the pages and copies in the Print Dialog Box, click the left mouse button on Ok to print the results. Click on Cancel Button to abort.

7.3 FAULT ISOLATION RESULTS

After the Structure-Based Connectionist Network (SBCN) performs fault isolation the results are usually displayed in color coded format mode. The following options lets you view and print these isolation results:

Color Coded Format Mode
Viewing Fault Isolation Results in View Mode
Printing Fault Isolation Results in View Mode
Printing Fault Isolation Results

7.3.1 COLOR CODED FORMAT MODE

To view diagnostic results in color coded format mode, select menu item Diagnosis-Fault Isolation Only. DAG calls the Structure-Based Connectionist Network (SBCN) to perform fault isolation by calculating fault possibility values for subsystems and components. After performing the fault isolation, select menu item Diagnosis-Show Color Result to display the results from faulty component isolation in a color coded format.

In the color coded format, colors are used to represent various fault possibility values for components. Accordingly, a bright red color represents a fault possibility value between 0.9 and 1, while a dark blue represents a fault possibility value between 0 and 0.1. The eight intermediate colors between bright red and dark blue represent fault possibility values at intervals of 0.1. For example, the color dull red which is immediately after bright red represents fault possibility values between 0.8 to 0.9. Using this color representation, DAG draws a color-coded square around each of the gearbox component icons with the corresponding fault possibility value for it listed on immediately on top of the component icon.

The first set of results that appear in the DAG window correspond to diagnostic results from the first pattern in test data files for sensors (see SENSOR DATA FILE FORMAT). In order to view results for the next pattern, use the dialog box at the bottom of the DAG window titled 'Diagnostic Results' which appears at the same time as color coded results appear. By clicking the left mouse button on the Next Button, results for the next pattern are presented, while clicking it on the Previous Button will display results for the pattern preceding the current one. Ok or Cancel Buttons will exit the color coded display.

7.3.2 VIEWING FAULT ISOLATION RESULTS IN VIEW MODE

The second method of viewing fault isolation results is the View Mode. This mode which is similar to the fault detection view mode display, can be activated by selecting the menu item File-View Results. The DAG window with component icons would be erased and a view mode window appears. In this mode, results are displayed in a square box representing the paper (they would appear exactly the same if they were printed using a printer). Note that results will appear in full page mode initially and may be too small to see. Click the left mouse button on the button Zoom In at the top of screen. The results will be re-displayed on the screen in an enlarged format. Click on the same button to zoom in more into the results, while click on the Zoom Out Button to zoom out to full page mode.

The diagnostic results from the Structure-Based Connectionist Network (SBCN) would be titled

STRUCTURE-BASED CONNECTIONIST NETWORK: FAULT SUBSYSTEM ISOLATION RESULTS.

The table under this title shows the fault possibility values associated with faulty subsystems obtained from the first sub-section of SBCN. The first column in this table is titled 'Pat' representing the pattern number. The total number of patterns in this table corresponds to the number of patterns (total number of feature vectors) entered in the Sensor Dialog Box (see CREATING A SENSOR). Column two onwards represent the fault possibility values for each subsystem. The results in each column are titled 'SS 1', 'SS 2', etc. representing subsystems 1, 2, etc. The fault possibility values are numbers between 0 and 1 with a 0 representing normal component and a 1 representing a definite fault in the component.

The fault component isolation results from the second sub-section of SBCN are titled

STRUCTURE-BASED CONNECTIONIST NETWORK: FAULT COMPONENT ISOLATION RESULTS.

The table under this title shows the fault possibility values for faulty components. The first column in this table is titled 'Pat', and as before represents the pattern number. The total number of patterns in this table corresponds to the number of patterns entered in the Sensor Dialog Box (see CREATING A SENSOR). Column two onwards represent the fault possibility values for each component. The results in each column are titled with name of the component in short form of each component (e.g., Spiral Bevel Pinion's short form is SBP). The fault possibility values are numbers between 0 and 1 with a 0 representing normal component and a 1 representing a definite fault in the component. Note that if the number of components in the gearbox is large, and all the component results do not fit in one table, a separate table titled

Faulty Component Isolation Results. Continued...

would appear to present results for the rest of components.

7.4 PRINTING THE GEARBOX STRUCTURE

DAG has facilities for the user to obtain to both view and print a hard copy of the gearbox structure that appears in the DAG window and the compulsory information on components. The following options allow the user to view and print the gearbox structure

Viewing The Gearbox Structure in View Mode
Printing Gearbox Structure From View Mode
Printing The Gearbox Structure

7.4.1 VIEWING THE GEARBOX STRUCTURE

In order to view the gearbox as it would appear when printed on paper, select menu item File-View Gearbox.

DAG changes the screen to view mode. In this mode the gearbox structure is printed in a square box corresponding to the printer paper size. The gearbox structure will be titled

SCHEMATIC OF GEARBOX: Name of gearbox (e.g., OH-58A).

Below this title, the gearbox structure with component icons and lines connecting these icons appears. Below the gearbox structure, tables presenting information on each of the component families (e.g., gears, bearings, etc.) appears. The first table presents information on the sensor family in the gearbox. The first column in this table lists the short name of the sensor (e.g., Sensor 1 has short name S1). Its long form (Sensor 1) appear in the second column. In the third column, the test data file associated with sensor is listed with the number of features number of patterns in each of these test data files listed in the fourth and fifth columns, respectively. In the sixth and seventh columns, the normal data file and the number of normal patterns associated with sensors are listed, respectively.

The gear, bearing and shaft family information is presented in the next three tables following the sensor family information table. Only the compulsory items for each of the components is listed in the tables. These items include, the short name in the first column, its long form in the second column and the subsystem the component belongs to in the third column.

7.4.2 PRINTING GEARBOX FROM VIEW MODE

The gearbox structure can also be printed from the view mode. View mode is activated when the menu item File-View Gearbox is selected. The results shown in this mode will appear exactly as they are printed on paper.

To print from view mode, click the left mouse button on the Print Button at the top left hand corner of the view window. A Print Dialog Box will appear. Clicking the left mouse button on the Ok Button will print the results, while clicking on Cancel Button will abort printing.

7.4.3 PRINTING THE GEARBOX

The gearbox structure can be printed using a printer installed in Windows 3.1. To print the gearbox, select menu item File-Print Gearbox. A Print Dialog Box appears, wherein the user can select the pages to printed, and the number of copies to produce. Clicking the left mouse button on the Setup Button in the Print Dialog Box, a Printer Setup dialog box appears. In this dialog box the user can select the printer to be used, the orientation (portrait or landscape), paper size

and source tray. A further Options Button in this dialog box allow the user to control the print intensity (light or dark) and dithering (coarse, fine, etc.).

After selecting the pages and copies in the Print Dialog Box, click the left mouse button on Ok to print the results. Click on Cancel Button to abort.

7.5 PRINTING INFLUENCE TABLES

DAG has facilities for the user to obtain a hard copy of the structural and featural influence tables. The tables, which represent the diagnostic knowledge for the gearbox, are usually viewed and edited using the menu item Influences-Modify Structural Influences and Influences-Modify Featural Influences (see STEP 3: CREATE SUBSYSTEMS, STEP 4: ADD FEATURAL INFLUENCES). The following options allow the user to view and print the influence tables

Viewing The Influence Tables in View Mode
Printing The Influences From View Mode
Printing The Influence Tables

7.5.1 VIEWING THE INFLUENCE TABLES IN VIEW MODE

In order to view the influences as it would appear when printed on paper, select menu item File-View Influences. DAG changes the screen to view mode. In this mode the influences are printed in a square box corresponding to the printer paper size. The first table is titled

Name of gearbox (e.g., OH-58A): STRUCTURAL INFLUENCE TABLE

The first column in the table, represents the sensors, and each subsequent columns represents the components. In the first row of this table, the titles for each column appear with title for first column being Sensor and the title for subsequent columns being the short form names of the components (e.g., Spiral Bevel Pinion has short form SBP). In the second row of the table, information on the subsystems each of the components belongs to appears. From third row onwards, structural influences between the sensors and components appear, with D, H, M, L, and - representing the influences Definite, High, Medium, Low, and Nil, respectively.

In the second table following immediately after the first, the featural influences are listed. This table is titled

Name of gearbox (e.g., OH-58A): FEATURAL INFLUENCE TABLE

The first column in the table, represents the features while the second column titled 'Grp' represents the group the feature belongs to. Each subsequent columns represents the components in the gearbox. From third column, second row onwards, featural influences between the features and components are listed, with D, H, M, L, and - representing the influences Definite, High, Medium, Low, and Nil, respectively.

7.5.2 PRINTING THE INFLUENCES FROM VIEW MODE

The influence tables can also be printed from the view mode. View mode is activated when the menu item File-View Influences is selected. The results shown in this mode will appear exactly as they are printed on paper.

To print from view mode, click the left mouse button on the Print Button at the top left hand corner of the view window. A Print Dialog Box will appear. Clicking the left mouse button on the Ok Button will print the results, while clicking on Cancel Button will abort printing.

7.5.3 PRINTING THE INFLUENCE TABLES

The influence tables can be printed using a printer installed in Windows 3.1. To print the influences, select menu item File-Print Influences. A Print Dialog Box appears, wherein the user can select the pages to printed, and the number of copies to produce. Clicking the left mouse button on the Setup Button in the Print Dialog Box, a Printer Setup dialog box appears. In this dialog box the user can select the printer to be used, the orientation (portrait or landscape), paper size and source tray. A further Options Button in this dialog box allow the user to control the print intensity (light or dark) and dithering (coarse, fine, etc.).

After selecting the pages and copies in the Print Dialog Box, click the left mouse button on Ok to print the results. Click on Cancel Button to abort.

8. LIMITATIONS OF DAG SOFTWARE

Although the DAG software is designed to be flexible to user's needs, it does have the following limitations arising due to memory allocation limitations.

The following are the maximum number of items the DAG software can handle.

Maximum number of icons (both component and sensor icons)	100
Maximum number of connections between icons	100
Maximum number of intermediate nodes for a given connection line between two components	10
Maximum number of vibration travel paths	100
Maximum number of components in a vibration travel path	25
Maximum number of vibration features DAG can handle	100
Maximum number of standard features	100
Maximum number of days/patterns/snapshots per test set DAG can handle	100

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13. ABSTRACT (Maximum 200 words) This document describes the Diagnostic Analyzer for Gearboxes (DAG) software for performing fault diagnosis of gearboxes. First, the user would construct a graphical representation of the gearbox using the gear, bearing, shaft, and sensor tools contained in the DAG software. Next, a set of vibration features obtained by processing the vibration signals recorded from the gearbox using a signal analyzer is required. Given this information, the DAG software uses an unsupervised neural network referred to as the Fault Detection Network (FDN) to identify the occurrence of faults, and a pattern classifier called Single Category-Based Classifier (SCBC) for abnormality scaling of individual vibration features. The abnormally-scaled vibration features are then used as inputs to a Structure-Based Connectionist Network (SBCN) for identifying faults in gearbox subsystems and components. The weights of the SBCN represent its diagnostic knowledge and are derived from the structure of the gearbox graphically presented in DAG. The outputs of SBCN are fault possibility values between 0 and 1 for individual subsystems and components in the gearbox with a 1 representing a definite fault and a 0 representing normality. This manual describes the steps involved in creating the diagnostic gearbox model, along with the options and analysis tools of the DAG software.
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